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PARTNERSHIP FOR A NEW GENERATION OF VEHICLES (PNGV): ASSESSMENT OF PROGRAM GOALS, ACTIVITIES AND PRIORITIES

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Partnership for a New Generation of...

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

OF THE

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTH CONGRESS

SECOND SESSION

JULY 30, 1996

[No. 75]

Printed for the use of the Committee on Science

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CONTENTS

WITNESSES

Page

July 30, 1996:

Panel 1:

Honorable Lionel S. Johns, Associate Director for Technology, Office of Science and Technology Policy 3

Robert M. Chapman, Chairman, PNGV Government Technical Task Force, United States Department of Commerce, testifying on behalf of Dr. Mary Lowe Good, Under Secretary for Technology, U.S. Department of Commerce 20

Dr. Joseph Bordogna, Assistant Director for Engineering, National Science Foundation 30

Thomas J. Gross, Deputy Assistant Secretary, Office of Transportation Technologies, United States Department of Energy 37

Panel 2:

Robert F. Mull, PNGV Director, Ford Motor Company, accompanied by: Peter M. Rosenfeld, PNGV Director, Chrysler Corporation, and Dr. Ronald E. York, PNGV Director, General Motors Corporation 65

Trever O. Jones, Chairman of the Board (retired), Libbey-Owens-Ford Company, and Chairman, PNGV Standing Committee, National Research Council 82

Dr. Robert L. Hirsch, President, The Energy Technology Collaborative, Inc., and Member, PNGV Standing Committee, National Research Council 102

Professor Daniel Sperling, Director, Institute of Transportation Studies, University of California, Davis 110

APPENDIX I—OPENING STATEMENTS

Congressman Vernon J. Ehlers, presiding Chairman, Subcommittee on Energy and Environment 125

Congressman Tim Roemer, Ranking Minority Member of the Subcommittee on Energy and Environment 127

Congressman James A. Barcia 133

Congresswoman Sheila Jackson Lee 134

APPENDIX II—ANSWERS SUBMITTED BY WITNESSES TO QUESTIONS OF THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Panel 1:

Honorable Lionel S. Johns, Associate Director for Technology, Office of Science and Technology Policy, The White House 136

Mr. Robert M. Chapman, Chairman, PNGV Government Task Force, U.S. Department of Commerce 143

Mr. Joseph Bordogna, Assistant Director for Engineering, National Science Foundation 155

Mr. Thomas J. Gross, Deputy Assistant Secretary for Transportation Technologies, Office of Energy Efficiency and Renewable Energy, Department of Energy 159

Panel 2: Page
Ford Motor Company, Chrysler Corporation, and General Motors Corporation 183
Mr. Trever O. Jones, Chariman of the Board (retired), Libbey-Owens-Ford Company, and Chairman, PNGV Standing Committee, National Research Council 198
Dr. Robert Hirsch, President, Energy Technology Collaborative, Inc., and Chairman of the Subgroup on Program Management of the National Research Council Committee to Review the Research Program of the PNGV 205
Professor Daniel Sperling, Director, Institute of Transportation Studies, University of California, Davis 207

APPENDIX III—ADDITIONAL MATERIAL FOR THE RECORD

Statement for the record submitted by Dr. Jay O. Keller, Hydrogen Program Manager, Sandia National Laboratories, Livermore, California 212
Review of the Research Program of the Partnership for a New Generation of Vehicles, Second Report, National Research Council Board on Energy and Environmental Systems and Transportation Research Board Standing Committee to Review the Partnership for a New Generation of Vehicles, (Washington, DC.; National Academy Press, 1996) 215
PNGV Technical Accomplishments, 1996, U.S. Department of Commerce and U.S. Council for Automotive Research 325
PNGV Program Plan, November 29, 1995, U.S. Department of Commerce and U.S. Council for Automotive Research 394
Inventions Needed for PNGV, March 1995, The Government PNGV Secretariat, U.S. Department of Commerce 440

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES (PNGV): ASSESSMENT OF PROGRAM GOALS, ACTIVITIES AND PRIORITIES

TUESDAY, JULY 30, 1996

U.S. House of Representatives,
Committee on Science,
Subcommittee on Energy and Environment,
Washington, DC.

The Subcommittee convened at 1:05 p.m. in room 2318 of the Rayburn House Office Building, the Honorable Vernon J. Ehlers presiding.

Mr. Ehlers. The meeting of the Subcommittee on Energy and Environment will come to order.

I am pleased to conduct this hearing on the PNGV, which are not the call letters for a new TV station, and not even digital TV, but rather stands for Partnership for a New Generation of Vehicles program which has been underway for a few years, and I would like to welcome all Members of the Subcommittee and witnesses to this oversight hearing on the Partnership for a New Generation of Vehicles.

This is an interesting, ambitious and complex project involving several government agencies and the automobile industry comprised of General Motors Corporation, Ford Motor Company and Chrysler Corporation in what is termed by the Administration as a departure from the historical primarily regulatory relationship between government and the U.S. auto industry.

The PNGV program is a joint cooperative research and development program between the Federal Government and the United States Council for Automotive Research, better known as USCAR, which was formed by Chrysler, Ford and General Motors. The PNGV program has its roots in the clean car initiative which was launched by President Clinton and Vice President Gore on September 29, 1993 with three specified goals of:

First, significantly improving national competitiveness in manufacturing;

Second, implementing commercially viable innovation from ongoing research on conventional vehicles; and

Third, developing a vehicle to achieve up to three times the fuel efficiency of today's comparable vehicles while maintaining or improving performance and cost and meeting or exceeding current federal safety and emission requirements.

The PNGV program was established with the aim of enhancing U.S. automotive industrial competitiveness by providing a focus and pushing the boundaries of technology. It's appears that the PNGV program goals one and two were designed with a short-term outcome in mind and may have reached a stage that no longer warrants an extensive involvement by the Federal Government.

Goal three presents a more ambitious and significant improvement of the automobile that Americans can drive and one that can perhaps improve the United States auto industry's global competitiveness.

Therefore the main purpose of this hearing is in the PNGV organization, program goals, Federal Government management of the program, the role of involved agencies, funding, accomplishments to date, priorities and the level of confidence in meeting technical schedules and milestones. These points are particularly relevant to goal three.

Furthermore, I am interested in examining the recommendations resulting from the Natural Research Council's annual reviews of the PNGV program and the PNGV's program's responsiveness to these recommendations.

I personally believe strongly in the peer review process, having been subjected to it myself as a scientist, especially when the funding from taxpayers is involved. I believe that such a peer review process should become a permanent part of the PNGV operation.

The PNGV funding situation is somewhat confusing and, in all fairness, difficult to track. Given the complex organization and nature of the program, it is even more important to have the cooperation of all the agencies and the USCAR to determine the real contribution from the Federal Government and the actual cost sharing by the auto industry.

This would provide for a healthy and objective debate that can focus on the substantive policy and technical issues. We need to determine what are the appropriate levels and areas of government involvement and whether government funds are being invested and used wisely.

Putting it in a slightly different context, the question that comes up is: why in the world should the Federal Government provide a substantial amount of money, amounting to hundreds of millions of dollars, to the three largest corporations, or combined the largest corporations in the United States and the world, whose worst years have not equalled the annual loss of the Federal Government and whose best years put the U.S. Government to shame?

At the same time, on the other hand, we have individuals who say this is a marvelous example of partnership between government and industry. The government plays a key role in bringing together competitors on a project where they can all bring resources to it as well as the Federal Government's resources and can make far greater progress than they could without the program.

So the purpose of this hearing is to look at the facts, the data, the information and try to reach an appropriate judgment which will be somewhere between the two extremes which I just cited.

Having made those comments I now recognize Ms. Rivers representing the Minority side for any remarks she might wish to make.

Ms. RIVERS. I have no remarks. Can Mr. Roemer make his opening remarks when he arrives or submit them for the record?

Mr. EHLERS. Yes, Mr. Roemer, if he arrives, can make his opening statement any time he wishes or submit it for the record, but I can assure you you're always representing the Minority side.

Ms. RIVERS. For a while anyway.

[Laughter.]

Mr. EHLERS. I do appreciate your attendance here and I hope you're able to remain for the full hearing. I deeply appreciate it, and I'm sure we both have a great deal of interest in this topic, not only because we're from Michigan, but because of the work we have done on this issue in the past.

We will recognize other Members for opening statements or at least putting them in the record should they appear at the hearing later.

I'm very pleased with the witnesses we have assembled. We have two distinguished panels. The first panel will represent primarily the government sector, and it consists first of all of the Honorable Lionel S. Johns, Associate Director for Technology of the Office of Science and Technology Policy. We have Mr. Robert Chapman, Chairman of the PNGV Government Technical Task Force, U.S. Department of Commerce; Dr. Joseph Bordogna, Assistant Director for Engineering at the National Science Foundation; and Mr. Thomas J. Gross, Deputy Assistant Secretary, Office of Transportation Technologies of the U.S. Department of Energy.

So we have all the Federal Government involvement, perhaps not all, but a majority of the Federal Government involvement represented at this table, and we look forward to your testimony.

Mr. Johns, we'll begin with you.

STATEMENT OF THE HONORABLE LIONEL S. JOHNS, ASSOCIATE DIRECTOR FOR TECHNOLOGY, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, THE WHITE HOUSE

Mr. JOHNS. Thank you, Mr. Chairman. It's a privilege to be here today. I appreciate the opportunity to talk about this program which we feel is an important program for the future of the country and for our economy.

I will submit my statement for the record and I will summarize the statement if I may.

One of the things that I was going to summarize were the PNGV goals, but you did that very nicely for me and I appreciate it.

At the beginning of this Administration's term I was one of the representatives in the White House that worked to craft this partnership, and I would like to focus on the reasons why we felt it was important to do that.

Now shortly after the inauguration, the President, the Vice President and the President's Science Advisor began considering how to best address difficult policy problems involving the transportation sector, specifically the environment and energy policy problems posed by our increasing reliance on the automobile.

Since vehicle miles traveled increased at the rate of about three percent a year over the last decade and consumers are favoring ever larger and less fuel efficient vehicles, the environment and policy issues are not being addressed by the marketplace. We realized that only a truly bold research project could provide the technology to address these policy issues, and the auto industry needed to be committed to the project in order for it to work.

The goals that you referred to, and notably the third goal, the very ambitious one of trying to increase the efficiency of automobiles by a factor of three while retaining the performance, the cost, the cost of operations and the safety of the vehicles was precisely what that third objective was.

The first two goals that you referred to are to improvements in manufacturing and the innovations that are along the road towards accomplishing the third goal, and our intent in having those earlier goals is in order to convey the intent of having progress incorporated as one moves along across a 10-year program.

Rather than unveiling a magical new car 10 years down the road, the R&D process is one which spawns new ideas which have different levels of commercial maturity, and those goals were intended to capture that. They are not, as you point out, end goals in themselves, but they are necessary to get to the end.

That third goal accomplishment, a factor of three, translates into family sedan sizes comparable to the Concorde for Chrysler, the Taurus for Ford and the Lumina for General Motors that gets an equivalent of 80 miles per gallon, is capable of accelerating from zero to 60 in 12 seconds or less, a range of 380 miles and an operating life of at least 100,000 miles.

To achieve the objective will require attaining technical targets such as doubling power source efficiency, reducing vehicle weights by at least 40 percent, cutting drag by a third, reducing rolling resistance by 40 percent and developing accessories that use 30 percent less energy. That is indeed a tall order, and it was only, I think, in this past year or so that we started to be optimistic about the chances of really achieving that.

On the economic front, the automobile created an industry that has provided high quality jobs for millions of Americans, and it has given birth to the mass production system. The automobile has brought a few problems with it as well—pollution, gridlock, new personal liabilities, and dependence on petroleum, a finite resource.

Nevertheless, the automobile is one of the great success stories of this country. Motor vehicles and equipment are the largest of all U.S. manufacturing industries; U.S. automakers, their dealers and suppliers provide over two million direct jobs; more than 13 million people work in related industries, one in seven of all American jobs; and the auto industry accounts for 4.5 percent of the U.S. GDP.

Today the auto industry is working to meet a variety of challenges, facing unprecedented competition, reaching out to global markets, coping with a rapid technological change and responding to environmental needs. The auto industry has been seriously engaged in adopting to the new competitive realities. For example, it has been at the forefront of adopting new production and management approaches even though this has often been a painful transition process. Yet, as we look to the future, new challenges for the industry and the nation lie ahead.

There is simply a limit to what we can do to achieve fuel economy and reduce pollution if efforts are limited to improving internal combustion engine technology and enhancing the performance of catalytic converters and other exhaust related components.

By the end of 1993 there were 194 million registered motor vehicles in the United States. These vehicles contributed a third of our smog-related air pollution and a third of our carbon dioxide emissions contributing to global climate change. And according to some projections, there could be nearly 270 million registered vehicles in the United States by the year 2010.

Now, this is the outlook for the United States. In many regions of the world, economic growth in the emerging industrial nations is lifting millions out of poverty and they, too, will be seeking the automobile.

The United States is highly dependent on petroleum, a resource we know to be finite and located primarily in other countries and for which there is an increasing worldwide competition. Indeed, the United States is becoming more dependent on foreign oil with each passing year. In 1995 imports accounted for 50 percent of U.S. oil consumption. Petroleum imports make up 10 percent of the nation's import inventory and account for a large chunk of the nation's trade deficit.

With domestic consumption growing at 1.1 percent a year and domestic production falling at 1.4 percent a year, the Energy Information Administration predicts that by the year 2000 imports will make up 56 percent of our consumption, and by 2010 imports are expected to exceed 60 percent of domestic consumption.

Fuel for ground transportation accounts for 43 percent of our petroleum-based demand. The current market forces alone will not get us where we want to be. Consumers today view quality and not fuel economy as the important factor in purchasing a new car or truck. While fuel economy ranked No. 2 to consumers in 1980, it ranks only No. 10 in 1990, and the biggest growth in the motor vehicle market continues to be the less fuel-efficient sports utilities, mini-vans, and pick-ups.

Clearly, the development and application of new technologies that would enable automobiles to consume less fuel and emit substantially less pollutants would have a profound effect on the United States and the world.

These factors indicate a clear convergence of public and private interests, and for this convergence that established the foundation for a partnership between the Federal Government and U.S. automakers to work together to achieve the technological breakthroughs required to produce a new class of highly efficient, environmentally-compatible vehicles.

In his 1993 technology policy statement, “Technology for America's Economic Growth: A New Direction to Build Economic Strength,” President Clinton committed to establishing such a partnership. Following six months of negotiations, the President and the CEOs of Chrysler, Ford, and General Motors announced the establishment of the Partnership for a New Generation of Vehicles in 1993. A public-private partnership between the Federal Government and USCAR, this research effort now involves the Big Three, seven federal agencies, including 18 national laboratories, numerous universities, and more than 350 automobile suppliers.

As you know, the Administration believes that the government support of long-term, high-risk R&D to assist in reaching the country's policy goals is not only appropriate but vital, and we feel strongly that the efforts by some in Congress during the last budget cycle to reduce or eliminate this spending is short-sighted and ignores the historic value to the country of such investment, which traditionally has enjoyed bipartisan support.

The Administration and the industry have worked closely with Congress to foster an understanding of our work and to explain in detail the needs for the funding requested. While we were unable to obtain the level of spending requested, we believe we have retained a viable program and are working with industry to get a maximum value for those expenditures. We are carefully examining each agency's ongoing project to assure maximum efficiency.

We see real technical progress, much of which is discussed in the Technical Accomplishments Report you have been provided. If this project is permitted to work, I believe it will. We need to be able to maintain our budget, and we need, and I believe deserve, the support of the legislative branch.

I'll be happy to answer any questions that you may have.

I would like to point out that a Technical Accomplishments document prepared with our cooperation by USCAR helps to summarize some of these near-term gains that we have made as a result of this program, and I think it's only the beginning.

Thank you very much, sir.

[The prepared statement of Mr. Johns follows:]

Testimony of

The Honorable Lionel S. Johns

Associate Director for Technology

Office of Science and Technology Policy

The White House

before the

Committee on Science

Subcommittee on Energy and Environment

U.S. House of Representatives

on the subject of

The Partnership for a New Generation Vehicle

July 30, 1996

Mr. Chairman and members of the subcommittee, thank you for giving me the opportunity to review the status of the Partnership for a New Generation of Vehicles, or PNGV. As a representative of one of the White House offices that worked to craft the partnership in 1993, I would like to focus my testimony on the Administration's reasons for entering into the partnership, and for believing that it can and should be a prototype for solving certain policy problems in the future.

Shortly after the inauguration, the President, Vice President, and the President's Science Advisor began considering how best to address difficult policy problems involving the transportation sector -- specifically, the environmental and energy policy problems posed by our ever-increasing reliance on the automobile. This work was also informed by a recognition of the impact of the auto industry on the economy, and the importance of its success to expansion of high-wage employment in this country.

Since vehicle miles traveled has increased at a rate of about 3% per year over the last decade, and consumers are favoring ever-larger and less fuel efficient vehicles, the environmental and energy policy issues are not being addressed by the marketplace. We realized that only a truly bold research project could provide the technology to address these policy issues, and that the auto industry needed to be committed to that project in order for it to work.

Thus, the government began its work toward a PNGV project as part of its responsibility to address two very difficult policy issues discussed below. We also believed that, over the long range, the industry that solved these policy problems could capture an increasing share of the world market. Given the importance of the auto industry to our economy and our job market, we recognized that working with the industry to solve our policy problems would also be tremendously beneficial to our economy.

PNGV Goals

The PNGV research and development agenda is focused on achieving three goals:

First, PNGV aims to improve manufacturing competitiveness significantly by upgrading manufacturing technology. We expect this will lead to reductions in cost and lead times, allowing U.S. automakers to respond quickly to changes in consumer preferences and seize market opportunities. This includes advances in design for manufacturing, rapid prototyping, intelligent processes, and agile manufacturing.

Second, we want viable innovations resulting from ongoing research to be applied to conventional vehicles and rapidly commercialized. Technologies that will improve fuel efficiency and reduce emissions will be especially important.

Our third goal is our most ambitious: to develop, within the next decade, a class of vehicles that will be up to three times more fuel efficient than today's cars. These vehicles should also cost no more to own and operate; offer comparable performance, roominess, and utility; and meet or exceed all safety and emission requirements.

This translates into a family sedan-size vehicle such as a Concorde, Taurus, or Lumina that gets the equivalent of 80 miles per gallon, is capable of accelerating from zero to 60 in 12 seconds or less, has a range of 380 miles, and has an operating life of at least 100,000 miles.

To achieve this objective will require attaining technical targets such as doubling power source efficiency, reducing vehicle weight by at least 40 percent, cutting drag by a third, reducing rolling resistance by 40 percent, and developing accessories that use 30 percent less energy.

It's a tall order, but we think it's within our reach.

Central Role of The Automobile in 20th Century American Life

Since Henry Ford's Model T first rolled off the assembly line in 1908, the automobile has played a central role in American life. As a driver of social change, the automobile reshaped our cities, suburbs, and home designs. It changed our work lives, shopping habits, vacation patterns, and even our courting rituals.

On the economic front, the automobile created an industry that has provided high quality jobs for millions of Americans. This industry also gave birth to the mass production system -- a new way of manufacturing that was adopted worldwide in nearly every industry, a system that fueled U.S. productivity and economic growth for most of this century. In addition to those employed directly in the making of cars, the automobile spawned new lines of business -- in insurance, banking, and sales; road and highway construction; oil refining; service stations; infrastructure for car care; drive-in theaters, and drive-up restaurants.

Of course, the automobile brought a few problems with it as well -- pollution; gridlock; new personal liabilities; and dependence on petroleum, a finite resource.

Nevertheless, the automobile remains one of America's greatest success stories. For example:

- motor vehicles and equipment are the largest of all U.S. manufacturing industries;
- U.S. automakers, their dealers, and suppliers provide over two million direct jobs -- more than 13 million people work in related industries -- one in seven of all American jobs;
- the auto industry accounts for 4.5 percent of U.S. GDP.

Today, the automotive industry is working to meet a variety of challenges: facing unprecedented competition, reaching-out to global markets, coping with rapid technological change, and responding to environmental needs. The automotive industry has been seriously engaged in adapting to the new competitive realities. For example, it has been at the forefront of adopting new production and management approaches even though this has often been a painful transformation process. Yet, as we look to the future, new challenges for the industry and the Nation lie ahead.

World Economic Growth and Pollution

There is simply a limit to what we can do to achieve fuel economy and reduce pollution if efforts are limited to improving internal combustion engine technology and enhancing the performance of catalytic converters and other exhaust-related components.

By the end of 1993, there were 194 million registered motor vehicles in the United States. These vehicles contribute a third of our smog-related air pollution, and one-third of our carbon dioxide emissions contributing to global climate change. And, according to some projections, there could be nearly 270 million registered vehicles in the United States by the year 2010.

There have been significant advances in producing vehicles that emit fewer pollutants. However, there will come a time when automotive emission control technologies will not be able to keep up with increases in the number of vehicles on the road and vehicle miles traveled. In addition, only improvements in fuel efficiency will address emission of carbon dioxide, since each gallon of gasoline burned relates directly to carbon dioxide emissions. Our vehicles may emit fewer pollutants, but there will be so many more of them in use that automobile-generated pollution will, nevertheless, remain a problem.

And this is the outlook for only the United States. In many regions of the world, economic growth in the emerging industrial nations is lifting millions out of poverty. In East Asia alone, the number of poor has fallen from 400 million in 1970 to 180 million in 1990, and China has lifted an estimated 175 million people out of poverty. These nations are now expanding their road systems and establishing other infrastructure. As time goes on, more and more of these people will achieve "middle class" status and the demand for automobiles will grow. China projects that its domestic market will grow from 180,000 autos in 1992, to 1.5 million in 2003 -- an annual average growth rate of more that 66 percent. Auto sales in South Korea already reached 1.5 million in 1993, and 15 percent annual average growth is projected for several years.

U.S. Dependence on Finite Oil Resources

The United States is highly dependent on petroleum, a resource we know to be finite and located primarily in other countries, and for which there will be increasing worldwide competition. Indeed, the U.S. is becoming more dependent on foreign oil with each passing year. In 1995, imports accounted for 50 percent of U.S. oil consumption. Petroleum imports make up ten percent of the Nation's import inventory and account for a large chunk of the Nation's trade deficit. With domestic consumption growing 1.1 percent a year, and domestic production falling 1.4 percent a year, the Energy Information Administration predicts that by the year 2000, imports will make up 56 percent of our consumption. By 2010, imports are expected to exceed 60 percent of domestic consumption. As the economies of the emerging nations continue to grow, so too will their demand for oil.

Fuel for ground transportation accounts for 43 percent of our petroleum-based energy demand. When we find ways to get more for each dollar spent on a barrel of oil, it helps us reduce our growing dependence on this finite resource. Also by the year 2010, two-thirds of the oil traded on the world market is projected to come from the Persian Gulf, a region of persistent political instability. Protecting our economic interests in this region is a challenge.

Fuel Economy Not High On List of Consumer Demands

Third, current market forces alone will not get us where we want to be. Consumers today view quality -- not fuel economy -- as the most important factor in purchasing a new car or truck. Quality ranked number one to consumers in 1980 after the Iranian Oil Crisis, and number one in 1990 when gas prices were relatively cheap.

But, while fuel economy ranked number two to consumers in 1980, it ranked only number ten in 1990. And, the biggest growth in the motor vehicle market continues to be in the less fuel-efficient sport utilities, mini-vans, and pick-ups.

Jobs, Economic Growth, and Foreign Competition

It is clear that a competitive advantage that will flow, over the long term, to companies that are among the first to market with a PNGV-like vehicle. Indeed, the economic benefits that will accrue to those companies' home nations and citizens is not lost on America's chief competitors in the global marketplace. Nations around the world have moved quickly to emulate PNGV and expand their existing collaborations with industry.

For example, the government of Japan has worked in partnership with its automobile industry for years, and has supported electric vehicle-related research since 1971. We believe that the Japanese budget for a PNGV-type vehicle dwarfs the PNGV budget, and that Japan has pledged to double its overall R&D funding by the year 2000.

The European Union has also entered the race to create a PNGV-type vehicle. "The Car of Tomorrow" initiative is providing substantial funding to EUCAR (European Council for Automotive R&D), a consortium of European car makers similar to USCAR. EUCAR participants include BMW, Mercedes, Fiat, Ford Europe, Opel, Peugeot-Citroen, Renault, Rover, Volkswagen, and Volvo. EUCAR has a proposed 5-year government-funded budget of $2.3 billion, and its program plan, goals and objectives mirror those of PNGV.

What seems clear is that the European and Japanese governments will continue to provide substantial funding and support to their auto industries to produce a PNGV-type vehicle regardless of the technical progress or U.S. government support of PNGV.

Foundations for A Government-Industry Partnership

As stated, the Administration began this work in an effort to solve environmental and energy problems that have been intractable, and in hopes that in solving these problems we would help improve the economy and create jobs. While the initial agreement was with the Big Three automakers who will compete by bringing the vehicles to market based on successful PNGV developments, we also knew that the partnership has to include as wide a group of research partners as possible for it to succeed.

Clearly, the development and application of new technologies that would enable automobiles to consume less fuel and emit substantially less pollutants would have profound effects for the United States and the world:

- create a healthier global environment by reducing vehicle pollution;
- improve U.S. national security by reducing our reliance on oil;
- improve the Nation's balance of trade by reducing oil imports;
- extend the life of the world's high-end petroleum resources by using them more efficiently;
- increase the competitiveness of the U.S. auto industry;
- open new markets across the globe;
- protect existing high-wage jobs and create new ones.

These factors indicate a clear convergence of public and private interests. And it is this convergence that established the foundation for a partnership between the Federal government and U.S. automakers to work together to achieve the technological breakthroughs required to produce a new class of highly energy-efficient and environmentally-compatible vehicles.

In his 1993 technology policy statement, *Technology for America's Economic Growth: A New Direction to Build Economic Strength*, President Clinton committed to establishing such a partnership. Following six months of negotiations, the President and the CEOs of Chrysler, Ford, and General Motors announced the establishment of the Partnership for a New Generation of Vehicles on September 29, 1993. A public-private partnership between the Federal government and USCAR, this cooperative research effort now involves the Big Three U.S. automakers, seven Federal agencies (including 18 national laboratories), numerous universities and more than 350 automotive suppliers in PNGV research.

Government and Industry Roles in PNGV

Both government and industry bring unique strengths to the table.

The industry partners have the capability to determine which product concepts make the most sense to bring to market; their expertise in mass production and marketing is essential to convert any advanced technical idea into a practical product.

Federal agencies have a resource of knowledge in advanced technologies and technical capabilities at their laboratories that can have direct relevance to the PNGV project. For example:

- The Commerce Department's capabilities lie in materials and advanced manufacturing;
- The Department of Defense has been particularly active in energy conversion and electrical systems R&D;
- The Energy Department has developed a comprehensive Electric and Hybrid Propulsion Program focusing on advanced batteries, fuel cells, and propulsion systems;
- The Department of Transportation brings crash safety expertise to the table;
- NASA's pertinent knowledge includes lightweight structures, fly wheels, high-temperature engine materials, fuel cells, and advanced electronics technologies;

- The National Science Foundation is our link to academic research institutions, doing basic and applied research in all fields;
- EPA's contribution includes emissions-testing expertise on alternative fuels and guidance on environmental matters.

The government has other responsibilities as well:

- We are working in consultation with our industry partners to set priorities for automotive-related government-sponsored R&D;
- We are working on an interagency basis to coordinate policies and programs that can contribute to the project;
- We are committed to facilitating the transfer of government-sponsored technologies to the industry in a timely manner.

Participants will share the cost of the project using a variety of arrangements -- direct funding of university research, funding of cost-shared research with industry, and government-industry cooperative research arrangements.

The relative proportions of government and private funding will vary depending on the specific project involved. The government's share of funding will be larger for high-risk projects where outcomes are uncertain -- areas in which technical risks are too great or returns too distant to justify adequate funding from the private sector. The industry share of funding will be larger for technologies with a clear, near-term market.

As you know, the Administration believes that government support of long-term high-risk R&D to assist in reaching the country's policy and economic goals is not only appropriate but vital. We feel strongly that the efforts by some in the Congress during the last budget cycle to reduce or eliminate this spending is short-sighted, and ignores the historic value to the country of such investment, which traditionally has enjoyed bipartisan support.

Notwithstanding such efforts, the Administration and the industry have worked closely with Congress to foster understanding of our work and to explain in detail the need for the funding requested. While we were unable to obtain the level of spending requested, we believe we have retained a viable program, and are working with industry to get the maximum value from those expenditures. We are carefully examining each agency's ongoing projects to assure maximum efficiency.

Conclusion

To summarize, we began this unique partnership as an effort to address significant public policy problems. We realized that we were taking on not only an enormous technical challenge, but also an unprecedented management challenge. We believe that now, almost three years into the program and having made some inevitable mistakes, we have a real working partnership with an effective management structure and technical teams that trust and inspire each other. We have broadened the partnership to include experts in business and academia well beyond the Big Three. We are seeing real technical progress, much of which is discussed in the Technical Accomplishments report you have been provided. If this project is permitted to work, I believe it will. We need to be able to maintain our budget, and we need, and I believe, deserve, the support of the Legislative Branch. I will be happy to answer any questions you may have.

Mr. EHLERS. Thank you for your comments. We will deal with questions after we have heard from everyone on the panel.

I would comment I have read the book you just held up, and it's very informative. I suspect we probably should produce a black and white copy for the Congress so they won't see how much money was spent in producing it since that's one thing they always look at.

Mr. JOHNS. Those were not taxpayer dollars, sir.

Mr. EHLERS. That's good to hear.

Before we go to the next witness I would like to recognize, or just acknowledge the presence of, Dr. Roscoe Bartlett who has joined us. We now have two-thirds of the scientists on the Committee present. And Congresswoman Rivers represents one of the greatest universities of the world in her district and certainly a very scientific one. So we have the scientific orientation here at this meeting today.

Mr. Chapman.

STATEMENT OF ROBERT M. CHAPMAN, CHAIRMAN, PNGV GOVERNMENT TECHNICAL TASK FORCE, U.S. DEPARTMENT OF COMMERCE

Mr. CHAPMAN. Good afternoon, Mr. Chairman. I'm Robert Chapman of the Department of Commerce.

As Chairman of the government's PNGV Technical Task Force I will be testifying for Dr. Mary Good, Commerce Under Secretary for Technology Administration, who was unable to attend this hearing. Dr. Good's written testimony discusses PNGV goals, management and progress in some detail, and I'll not repeat that.

I would like to focus my statement on two aspects, the government's role in PNGV and its financial support of this research program, which in a lot of cases has been a source of some misunderstanding in the past, and I think you referred to that in your opening statement.

As you know, the Partnership for a New Generation of Vehicles is an agreement between the Federal Government and the Big Three domestic automobile manufacturers. The government side itself may be characterized as a partnership also. There are currently seven federal agencies participating in the PNGV, with Commerce, where I reside, having the lead for government coordination.

The major objective of our activities is to ensure that the technologies resident in the government laboratories, or otherwise sponsored by the government and relevant to the PNGV, are shared with our auto industry partners. Industry in this case refers to suppliers as well as the OEMs, OEMs being Ford, Chrysler and GM.

There are 20 federal laboratories participating in this effort. One half of them are DOE labs, but nearly all the other agencies' laboratories are participating to some extent. NSF, as you may know, does not have any lab.

The PNGV Technical Accomplishments Report, which is again the one that Mr. Johns showed you, which we furnished and I believe all of you have that, lists 61 projects in which federal laboratories are actively involved. Twelve of these success stories, for example, are at Oak Ridge National Lab. Now that was for the benefit of Congressman Wamp, and I'm sorry he's not here, but you can tell him.

The question of the budget, "the budget for PNGV" requires some explanation. There are several reasons for this. First, there is no overall budget as such. There is no overall budget for PNGV as such. It's more appropriate to talk about the aggregate level of technical activity on PNGV than the funding level associated with that, and let me explain further.

The funding level, and note that I did not say budget, but the funding level of PNGV is approximately $293 million a year. Of this, roughly one-third goes to the federal laboratories to support their research projects and to support their interactions with auto industry engineers. One third goes to generally non-OEM suppliers by a direct contract for research from the Department of Energy, the National Science Foundation, the Advanced Technology Program at NIST and various small business innovation research programs. The balance, roughly one-third, goes to the OEMs. This supports specific PNGV-related systems engineering and similar precompetitive research. Of that funding, that is the funding that goes to the OEMs, roughly three-quarters is channeled to suppliers working with the OEMs.

The upshot is that, overall, roughly one-half of the PNGV funding goes to suppliers, some from the government directly and the balance from the auto companies, originated with the government but through the auto companies. The amount of money that actually "sticks" with the OEMs is less than 10 percent, roughly, of the total funding level.

Regarding the $293 million, which is the aggregate level of research activity we believe related to PNGV, about $120 million was identified as PNGV-related in agencies' FY-96 budget submissions. So it's traceable to something that was actually submitted in the budget.

These requests, by the way, were cut $60- to $70 million to bring us to our present operating level of 293. The balance of the funding, roughly one-half, is made up of a large number of research projects in the seven supporting agencies. Many of these projects were initiated before PNGV was formed to support research related to the agencies' statutory or traditional missions.

Subsequently, the PNGV Technical Task Force determined that these research projects had some significance or relevance to PNGV. They were then thus included in the technology base for the program.

So in general we have applied very little new funding to PNGV. The formation of this project was primarily an effort to focus related ongoing research. The PNGV label has been attached to a wide range of research projects that are considered to be, in whole or in part, able to support the PNGV goals.

The Accomplishments Report and our testimony should convey graphically that this is an undertaking which has the air of success. We want you to understand that, in the main, the research activity we are drawing upon within the government was underway prior to PNGV, and it has now been realigned to focus on PNGV goals.

Our ability to draw on the technology resources of the government and focus this research gives the partnership its momentum and puts us on track to succeed in meeting the challenging goals of this historic partnership.

Thank you, sir.

[The prepared statement of Dr. Good follows:]

TESTIMONY OF

DR. MARY LOWE GOOD

UNDER SECRETARY FOR TECHNOLOGY

TECHNOLOGY ADMINISTRATION

U.S. DEPARTMENT OF COMMERCE

BEFORE THE

COMMITTEE ON SCIENCE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

U.S. HOUSE OF REPRESENTATIVES

ON THE SUBJECT OF

THE PARTNERSHIP FOR A NEW GENERATION VEHICLE

JULY 30, 1996

Mr. Chairman and members of the subcommittee, thank you for giving me the opportunity to review the status of the Partnership for a New Generation of Vehicles, or PNGV.

For several years the Nation's leadership has engaged in a debate about the appropriate role of the Federal government in fostering technological innovation. Some advocate a hands-off approach, with a singular faith in unfettered markets. Others believe that today's highly competitive environment requires new forms of cooperation to ensure our Nation's leadership role in the global economy and high quality, high-wage jobs for American workers.

While clearly the private sector has primary responsibility for competitiveness, the Administration believes that the government can play an important role in fostering innovation. This is especially true in areas in which the achievement of technological objectives can bring widespread national social and economic benefits. I believe those committed to the continued leadership position of the United States will find that the Partnership for a New Generation of Vehicles offers benefits to the Nation that far exceed the relatively small Federal effort.

Why should the Federal government fund PNGV research?

Some have questioned why the Federal government should partner with American automobile manufacturers, especially at a time when the government is tightening its budget belt.

I would like to address that issue directly. There are four fundamental reasons why the Federal government must participate in this strategic partnership.

- The Federal government has unique assets to bring to bear on the technological challenges;
- PNGV offers high social returns to the nation;
- PNGV offers high economic benefits to the nation; and
- The absence of Federal support for PNGV could result in these benefits flowing to other nations as their firms—with the financial and technical assistance of their governments—reach the market first with PNGV-like vehicles.

Let me provide some examples:

First, a successful PNGV program will help us to meet important social goals for which government is responsible. As Mr. Skip Johns mentioned in his testimony, PNGV will reduce the amount of pollutants currently emitted by motor vehicles, and will ameliorate the environmental impact of tens of millions of new vehicles that will take to the roads in emerging industrial nations in the coming decades.

Second, PNGV will help us husband our planet's petroleum resources through increased fuel efficiency, ensuring that these resources will be available to future generations of Americans.

Third, by improving the fuel efficiency of automobiles, PNGV will help to offset the upward pressure on oil prices that will result from increased demand for petroleum products from the emerging industrial nations.

Fourth, improvements in fuel efficiency brought about by PNGV will reduce the amount of oil the United States must use which, among other benefits, will improve our balance of trade.

Fifth, the Federal government has scientific and technological assets that are unique in the world that would be economically infeasible, and in some cases simply impossible, for the private sector to replicate. Even if it were economically feasible and technically possible, these assets could not be replicated quickly enough to meet industry's time-based competitive requirements. The Federal role in PNGV allows U.S. auto manufacturers to avail themselves of these resources.

Sixth, the Partnership for a New Generation of Vehicles involves the development and application of many technologies that are characterized by high cost and high risk with delayed returns on investment. These characteristics make such research an unattractive investment for companies facing intense global competition, more immediate business concerns, and stockholder demands for short term performance. PNGV helps to reduce costs and risks in three ways.

1. First, PNGV—and industry-government partnerships in general—serves as a catalyst to bring together individual companies with common technology. By working together, these firms can share costs and risks of developing the required enabling technologies.
2. Second, by engaging in cooperative research and development agreements with Federal agencies, U.S. companies can tap the unparalleled technical resources of America's national laboratories—human and infrastructure—to overcome technological uncertainties.
3. And finally, through programs such as the Advanced Technology Program, the Federal government can reduce industry's technological risk—through technical and business evaluations— and reduce costs by entering into cost-sharing arrangements on proposals that offer broad-based economic benefits with high rates of social returns to the nation.

Seventh, the United States will reap substantial economic benefits from a successful PNGV program that enables American car makers to be first to the market. PNGV has the potential to boost the Nation's economic growth by strengthening one of America's most important industries. The motor vehicles and equipment industry is the largest of all U.S. manufacturing sectors. U.S. automakers, their dealers, and suppliers directly provide 2.3 million jobs, and more than 13 million people work in related industries. In total, the U.S. auto industry provides 1 in every 7 American jobs and accounts for 4.5 percent of GDP. Through a successful PNGV, we will be able to protect these high-wage jobs and create new ones as U.S. auto manufacturers tap new markets throughout the world. In the absence of a successful PNGV program, these benefits will accrue to other nations.

In summary, let me be direct—*PNGV is not corporate welfare*. Nor is it unfair support of America's Big 3 automakers. The purpose of PNGV is to develop the technological base from which the automotive industry—OEMs and suppliers alike—can draw to develop the next generation of vehicles. If this effort is successful—and there is every indication that it will be, provided that the Federal government sustains its role in the partnership—it will provide a model for similar collaborations between industry and government.

Let me also note that there is not a great deal of "new money" in the program. Most of the programs that comprise this initiative were in existence prior to the establishment of PNGV. We have made every effort to build on existing government and industry initiatives to fully exploit mechanisms already in place and to make more effective use of our resources. For example, government efforts include the work of the materials technology and manufacturing infrastructure subcommittees that operate under the Committee on Civilian Industrial Technology of the National Science and Technology Council. PNGV has helped focus these research efforts to achieve goal number three—a class of vehicles with three-fold energy efficiency.

With so much at stake, let me turn to the real progress that the government and the automakers have made in the year and a half since PNGV came together.

Accomplishments

Let me begin by mentioning our new report, *PNGV Technical Accomplishments*, which highlights the many accomplishments of PNGV to date. Incidentally, a copy of this publication was recently sent to each committee member. Thomas Gross, Deputy Assistant Secretary of Energy for Transportation Technologies, will discuss some of these successes in his testimony, as will the companies' representatives.

PNGV Management Structure

Great care and effort have been invested in the up-front planning of the organization and operation that will guide this research program throughout its duration. We have collaborated on a program plan and are establishing a World Wide Web site for PNGV where source documents, contact points, and the like are easily accessible.

We have established a management structure to oversee the development of the technologies needed to attain our goals. Under this structure, government and industry work together in an operational steering group responsible for policy and decision making. In my capacity as Under Secretary of Commerce for Technology, I chair the government's team which includes R&D officials from the participating seven Federal agencies. Industry's steering team consists of the Big 3's Vice Presidents for RD&T. Both partners maintain their own technical, legal, legislative, and public affairs teams. Additionally, the Commerce Department maintains a PNGV Secretariat.

This is a virtual organization in the sense that we have utilized or subsumed activities that were in existence at the time PNGV was formed. The United States Council for Automotive Research (USCAR), which was formed in 1992, prior to the establishment of PNGV, represents the Big 3 U.S. automakers in this initiative. There are now ten technical working teams and an additional six consortia or boards supporting PNGV, each with government laboratory technologists and industry engineers. This technical activity is managed by the PNGV Technical Executive Committee. Director-level people from Commerce and Energy serve on this committee with their counterparts from the OEMs. It is anticipated that this governance structure may establish the model for future multi-agency, government-industry ventures.

PNGV Progress

Early in the program, the auto industry identified fourteen principal technical areas necessary for achieving PNGV goals. To achieve a vehicle with three-fold fuel-efficiency—PNGV's goal three—five areas were identified as top priorities and technical roadmaps were then developed for each of these areas. Our industry partners will address these priorities and roadmaps in greater detail.

We also held collaborative workshops at USCAR in which the automakers and suppliers prepared detailed technical pathways, including milestones and metrics.

In the beginning, our first efforts were designed to identify what relevant programs were being carried out in the Federal government. We conducted an assessment of grant and contract programs, as well as Federal mission research. However, our most useful mechanism for informing our industry partners of the technology resources available in the government has been government laboratory visits. So far there have been 20 such meetings.

In efforts to achieve maximum efficiency, agencies have special management assignments based on their programs, missions, and core competencies:

- Policy direction is provided by the Office of the Vice President.
- Commerce is responsible for overall interagency coordination.
- Energy is responsible for managing the definition of the overall architecture of the vehicle systems.
- The National Research Council conducts a peer review process for independent confirmation of our priorities and resource commitments.

We are creating multiple idea paths to bring other players into the process, stimulate fresh ideas, and encourage new collaborative arrangements--drawing the best minds in industry, government, and academia into this effort. We have published a booklet called "*Inventions Needed for PNGV*" to encourage the participation of suppliers, small businesses, and entrepreneurs in PNGV. This publication pinpoints areas that need major improvements or innovations to ensure the technical goals of the program are met.

Programmatically, participation can be channeled through a number of existing government programs which can provide support for PNGV technologies—including the Advanced Technology Program, the Small Business Innovative Research Program, CRADAs with the labs, contracts with mission agencies, and the DOC/DOE Energy-Related Inventions Program. We have technology transfer mechanisms in place, such as cooperative research and development agreements (CRADAs), as well as provisions to protect intellectual property.

Next Steps

What remains to be done? First, let me say that we are on schedule. The PNGV team has developed a broad timetable for achieving its long-term goal of three-times improvement in fuel efficiency. We have had considerable success, most of which will be addressed by our industry partners later in this hearing. Our next important milestone is the selection of critical path technologies. This is scheduled to be completed by December 1997. By that time we expect industry will have identified the most promising of the advanced technologies for meeting PNGV's goal number three.

At this point no technology has met every objective, nor has any proven to be categorically untenable. Room temperature superconductors, risk-free flywheels, and efficient hydrogen storage devices are not yet in hand. The auto companies are narrowing their own foci based on their experience and judgment, but no technology will be eliminated from contention until we reach that point on our timeline.

As we approach the end of the decade, these technologies are expected to be applied to the concept vehicles. Production prototypes will then be developed during the period 2002-2004.

In fulfilling its PNGV role, the National Research Council recently published its second peer review. The review included recommendations in areas such as program management, funding and support, technology strategy, supplier and university involvement, and foreign technology. We were pleased by the general tone of the findings, especially the Committee's confirmation of our overall program strategy and the scope of our technical work. In particular, we were reassured by their belief that the technologies being pursued are relevant and appropriate to the Partnership's objectives. The Committee's recognition that our technical teams are organized effectively and are working well was also gratifying. We certainly agree that PNGV has a significant challenge to meet in a relatively short time frame. Our goals were purposely set high to accelerate the advance of automotive technology.

The NRC report contained a number of important findings and recommendations. The Partnership has studied these carefully and believe that the report provides helpful perspectives. Our intent is to respond to the major recommendations and enter into a more detailed dialogue during their next review.

Challenges Ahead

Looking to the future, I want to emphasize that development of the triple-efficiency car is only half the solution. We don't want to participate in a technical success which becomes a market failure.

For the next generation vehicle to be profitable and create economies of scale, the automakers will have to be able to sell many cars to the public. Yet, it is clear that volume sales will not occur unless consumers are confident that the routine automotive support services they take for granted today will be in place for whatever might replace or supplement the internal combustion engine.

While our focus is currently on the development of multiple technology pathways that will lead to the triple efficiency vehicle, as time goes by and technology choices are made, we will have to consider how to facilitate the development of a supporting infrastructure.

Conclusion

In closing, let me emphasize that PNGV is a unique and historic program. This initiative exemplifies the Clinton Administration's basic approach to technology and innovation—bold vision, concrete goals, and a strong partnership with industry. Government is working with industry to develop the required technologies, and industry will make the choices necessary to achieve a new generation vehicle that is embraced by the marketplace and achieves the Nation's social and economic objectives.

In the race for the future, the Federal government is serving as the pit crew for America's car makers. Industry is in the driver's seat, and the Federal government is providing pre-competitive technical support and infrastructure development. Only by working together can we ensure that the United States crosses the finish line ahead of our foreign competitors and takes the checkered flag in the global race to bring the next generation of fuel efficient vehicles to the world. If we take the flag, American workers will join Uncle Sam and the Big Three in the winner's circle as the market rewards the victors with high-wage jobs, economic growth, and wealth creation.

Thank you.

Response to

Questions for Panel 1: Representatives of the Federal Government

Answer to question 6. Systems analysis is one of the important approaches to model vehicle and subsystems decision making. Each company has its own systems modeling team to guide technology decisions. In addition, there is an independent, effective analysis underway funded by the government. This analysis allows for the integration of the systems as a whole without having to overcome proprietary issues of each company. There is an effective analysis underway; government is committed to funding this effort on an ongoing basis. We are holding to our schedule and we have not changed our technical goals.

The industry has always recognized the essential role of systems analysis in achieving vehicle and component development objectives as evidenced by a considerable and growing dedication of resources to modeling and computer analysis of vehicle designs. Discussions with the Federal agencies involved in the systems analysis effort have reaffirmed that PNGV systems analysis will remain a priority. All of our plans described in the Technical Roadmaps reflect its importance.

The OEMs have sophisticated proprietary modeling tools which have been used in support of the Hybrid Electric Vehicle development programs. Since the last Peer Review, the PNGV systems analysis activity has made substantial progress in developing a joint cross-calibrated vehicle modeling tool for trade studies. Existing component models have been acquired from the Federal labs and industry and, where needed, component models have been created or modified using the OEM's proprietary modeling capabilities. Verification of vehicle models is planned for this Summer, with initial trade studies scheduled for this Fall.

At this point the overall system analysis performance modal is complete and individual component models have been validated. An "application prototype" modeling tool will be available in August that will provide functional software for advanced vehicle performance evaluations. All the models required for a systems analysis are developed and verified. Additional tool enhancement and productionization are underway and will be developed by the end of the year. This includes sophisticated optimization techniques and more detailed body and chassis components. The goal of the system analysis effort is the development of a modeling tool that can be used to evaluated the vehicle performance of a wide range of system design options.

Mr. EHLERS. Thank you for your testimony.

Perhaps you could clarify for me just quickly. You chair the PNGV Government Technical Committee.

Mr. CHAPMAN. Yes, sir.

Mr. EHLERS. Later we have the Chair of the PNGV Standing Committee.

Mr. CHAPMAN. The Standing Committee of the NRC.

Mr. EHLERS. Of the NRC, okay. I'm just trying to get in my mind who is really running the show here. What role does your committee play versus the Standing Committee, and are there other governing committees here that I'm not aware of?

Mr. CHAPMAN. Well I think it's easier to clarify NRC in the sense that the National Research Council is chartered by Congress to give advice to the government upon request, and the declaration of intent for the PNGV at its origin stipulated that would be a peer review process conducted by the National Academy of Sciences of which the NRC is the operating arm for.

So they have sat in review, in a sense, an annual Board of Directors technical review of the program. They meet once a year roughly and have issued two reports. They're about to meet again in early September, and that's their function, the overall technical review of the program.

Within the government, as I mentioned, there are seven federal agencies participating, and each of those agencies, through their laboratories in support of research, are participating in the program. So basically my job is to coordinate that activity within the government and deal with members from the USCAR whom you'll hear from in the next testimony.

Mr. EHLERS. Thank you for clarifying that.

I would also like to acknowledge the appearance of Congressman Tim Roemer from Indiana, Ranking Member of this Committee.

Do you have an opening statement you wish to make?

Mr. ROEMER. Mr. Chairman, I do have an opening statement, but since I am late I would ask unanimous consent to enter it into the record as if read.

Mr. EHLERS. Without objection, so ordered. Thank you. We're happy you were able to make it.

Next is Dr. Bordogna from the National Science Foundation.

STATEMENT OF DR. JOSEPH BORDOGNA, ASSISTANT DIRECTOR FOR ENGINEERING, NATIONAL SCIENCE FOUNDATION

Dr. BORDOGNA. Thank you, Mr. Chairman. I'm pleased to be here today, and I would like to describe both the nature of NSF's investment in this effort and also its participation.

As you know from your experience, the National Science Foundation promotes the progress of science and engineering generally rather than focusing on a specific mission involving a narrowly defined science or technology area. Research and education concepts proposed to NSF are initiated by investigators and involve all science and engineering disciplines of scholarship and all levels of education and human resource development. This breadth of coverage gives NSF both the ability and the responsibility to foster different types of linkages, synergies and connections that are essential to enabling the nation's capacity to perform.

NSF guides its investments and fundamental research and education through four core strategies:

—Develop intellectual capital;

—Strengthen the physical infrastructure that enables the capital to work;

—Integrate research and education; and

—Promoting partnerships of all kinds.

Within this context NSF's investments support a wide array of fundamental research and education projects at universities. Many of these projects have led directly and indirectly to advances in automotive technology. Consistent with its mission, NSF does not issue requests for proposals explicitly focusing on PNGV and does not define a budget category around PNGV.

However, university researchers are often excited by research directions that could yield important breakthroughs in technological areas on which U.S. industry depends that are identified as national needs. When they submit proposals to NSF, their proposed work often concerns issues that PNGV has also identified as being of interest. Thus there is significant NSF investment in areas that advance the PNGV research agenda originated both by researchers well conversant with the PNGV efforts through NSF's supported workshops on PNGV, which I'll list in a moment, and also by those research investigators unaware that their work fits PNGV's defined categories.

The current portfolio of NSF-funded projects includes many that may influence the design, manufacture and use of future automobiles. In a careful study of this portfolio, NSF program directors have estimated that approximately $54 million of NSF support in fiscal '95 was for projects with the potential to improve the future design, production, use, disposal and recycling of automobiles, their accessories or components.

We are continually working with the other PNGV agencies and with the OMB to refine these estimates of NSF funding that are directly or indirectly relevant to PNGV. Most of these projects are integrated research and education awards involving individual university researchers or small groups of faculty along with graduate and undergraduate students. But the inventory also includes a number of SBIR projects, small business innovation projects, the university/industry collaborative projects and some of our centers.

All these individual projects were initiated by the investigator, reviewed by experts who assessed their quality, novelty and potential significance and awarded solely on the basis of overall merit. While the work itself aims to create new knowledge fundamental to many application areas, the connection between this long-term fundamental search for new knowledge and its ultimate impact on industry is exemplified in my written testimony with an example.

Mr. Chairman, the Science Committee has been a strong advocate for better cooperation and collaboration between private industry and the academic community. NSF shares this goal generally and believes that research in the area of automotive technology is a natural avenue to foster such cooperation.

As a result, NSF staff are interacting with representatives of Chrysler, Ford and General Motors and other manufacturing companies to explain the merit review process, expose the university research community to PNGV related technical issues, broker matches between industry experts and university researchers and encourage the participation of manufacturing industry experts in the review of research proposals to NSF.

An NSF/DOE conference on basic research needs for vehicles of the future was held in January of '95 in partnership with major U.S. automobile manufacturers and their suppliers. 188 participants from 34 different universities, 18 government agencies and 24 different companies in the automotive industry worked together for three days to define the key research problems critical to long-term research areas defined by the research staffs of Chrysler, Ford and GM.

A follow-on conference in January of '96 on basic research needs for environmentally responsive technologies of the future identified industry specific basic research opportunities in five industries, one of which was the automotive industry.

And there is a third conference being planned for late 1996 or early '97 to focus on long-term engineering research issues relevant to PNGV.

The dialogue between the automotive industry and university researchers has already had positive effects. For example, and I'm very excited about this, last month NSF announced a new award for an Engineering Research Center at the University of Michigan which can be considered an investment in PNGV research goals. This center was one of four new Engineering Research Centers this year selected in competitive merit review from among more than 100 candidates.

It brings Chrysler, Ford, GM, Caterpillar, General Dynamics, Boeing, United Technologies and 24 of their technology suppliers together with a team of university faculty and students to develop a new generation of low-cost machine systems that can be easily reconfigured to increase the flexibility of automotive, heavy vehicle and aircraft production.

NSF also supports a Materials Research Science and Engineering Center at Michigan State, a partnership between Michigan State, Chrysler, Ford and GM, established by NSF in 1994 to provide a focal point for fundamental research on materials and devices with high potential for application in vehicular sensing systems. There are 11 NSF-supported Industry/University Cooperative Research Centers with membership by the major auto companies.

It's important to emphasize that all of these NSF projects were awarded through a competitive merit review process in which there was no targeting of technology areas by NSF. Nevertheless, the range of technical topics covered among the proposed NSF receives correlate well with the PNGV emphasis areas. Leadership from the Federal Government in partnership with industry is having an impact on how the long-term research needs of U.S. industry are made known to the academic community, and this in turn influences how academic researchers plan their own individually conceived research and education goals.

Thank you.

[The prepared statement of Dr. Bordogna follows:]

Hearing on the Partnership for New Generation of Vehicles Program

Subcommittee on Energy and Environment
Committee on Science
U.S. House of Representatives
July 30, 1996

Statement of Dr. Joseph Bordogna
Assistant Director for Engineering
National Science Foundation

Mr. Chairman and members of the Subcommittee, I am very pleased to be here today to discuss the National Science Foundation's role in the Partnership for a New Generation of Vehicles (PNGV). I would like to present a brief explanation of the nature of NSF's investment and participation in this effort.

The National Science Foundation promotes the progress of science and engineering generally, rather than focusing on a specific mission involving a narrowly defined science or technology area. Research and education concepts proposed to NSF are initiated by the investigators and involve all science and engineering disciplines of scholarship and all levels of education and human resource development. This breadth of coverage gives NSF both the ability and the responsibility to foster the different types of linkages, synergies and connections that are essential to enabling the Nation's capacity to perform.

NSF has identified four core strategies that are designed to guide its investments in fundamental research and education:

- Develop Intellectual Capital -- invest in the best ideas and the most capable people to carry them out, including groups and regions that traditionally have been underrepresented in science and engineering, and contribute to developing the capacity for scientific and engineering excellence among all members of our society
- Strengthen the Physical Infrastructure -- improve the physical resources and information technologies available to pursue creative, innovative ideas and to create an environment in which effective progress is possible
- Integrate Research and Education -- support fundamental research in an education-rich environment and infuse education with experiences in discovery and exploration through directed inquiry, careful observation and analytic thinking at all levels
- Promote Partnerships -- collaborate with the academic community, industry, elementary and secondary schools, other Federal agencies, state and local governments and other institutions involved in science and engineering

Through its ongoing programs, NSF has supported a wide array of fundamental research and education projects at U. S. universities. Many of these projects have led, directly and indirectly, to advances in automotive technology. Consistent with its mission, NSF does not issue requests for proposals explicitly focusing on PNGV and does not define a budget category around PNGV. However, university researchers are often excited by research directions that could yield important breakthroughs in technological areas on which U.S. industry depends and that are identified as national needs. When they submit proposals to NSF, their proposed work often concerns issues that PNGV has also identified as being of interest. Thus there is significant NSF investment in areas that either directly or indirectly advance the PNGV research agenda, originated both by researchers well conversant with the PNGV efforts through NSF-supported PNGV-related workshops and also by those research investigators unaware that their work fits PNGV's defined categories, or even that this interagency effort exists.

Since a major criterion for funding by NSF is the potential for the discovery of new knowledge, it is difficult to predict at the proposal stage which specific projects will result in the critical understanding needed to make a particular technology feasible. However, experience has shown that if we select the most promising research ideas across a broad spectrum of engineering and science disciplines, many of the research results will be useful to industry, including the automotive industry. Indeed, the current portfolio of NSF-funded projects includes many that may influence the design, manufacture and use of future automobiles. In a careful study of NSF's investment portfolio, NSF program directors have estimated that approximately $54 million of NSF support in FY 1995 was for projects with the potential to improve the future design, production, use, disposal and recycling of automobiles, their accessories or components. We are continually working with the other PNGV agencies and with the Office of Management and Budget (OMB) to refine these estimates of NSF funding that is directly or indirectly relevant to PNGV. Most of these projects are integrated research and education awards involving individual university researchers or small groups of faculty along with graduate and undergraduate students, but the inventory also includes a number of small business innovation research (SBIR) projects, university-industry collaborative projects and centers.

NSF proposals are initiated by the investigator, reviewed by experts who can assess their quality, novelty and potential significance and awarded on the basis of overall merit. While the work itself aims to create new knowledge fundamental to many application areas, the researcher is often aware of a potential long-range goal.

The connection between a long-term, fundamental search for new knowledge and its ultimate impact on industry is exemplified by the search for new, more efficient ways to manufacture metal and thermoplastic composite joints -- critical for many components in an automobile -- without the need for a bonding agent or epoxy to hold the parts together. To achieve this goal, certain very fundamental questions about the microscopic surface characteristics of metals and thermoplastics must first be answered.

Currently, many of the manufactured components within an automobile contain metal and thermoplastic molded parts whose surfaces must be tightly bonded together. These component parts are now molded separately and then attached with epoxy. An NSF-supported researcher at Purdue University, Professor Karthik Ramani, and his students have been studying the microscopic surface characteristics of several commonly used metals and thermoplastics. They have discovered that under certain thermal and pressure conditions these different material surfaces can be made to bond well without epoxy. Their NSF-supported work will determine the fundamental mechanical and chemical properties of the oxidized surfaces of these metals and the detailed polymer chemistry of the thermoplastics. Using this knowledge along with sophisticated numerical modeling and multimedia simulation of the bonding process, these researchers may be able to suggest possible surface treatments for the two kinds of materials, as well as modified hot-melt and compression molding processes for manufacturing these components, that could be used to achieve maximum strength for the metal-thermoplastic bond.

The outcome of this fundamental research may be critical to how private industry will manufacture the next generation of automobiles. If the Purdue research team determines that the epoxy step could in fact be eliminated, this would decrease the overall cost and time required to manufacture any components with metal-thermoplastic composite joints, and could also make these components operate more reliably in automobiles and other systems. Of course, in addition to advancing PNGV needs, results from this research could also contribute to improving certain classes of biomedical implant devices, suspension linkages, airframe structures and metal bearing sleeves. Finally, an integral part of NSF support for this project is bringing the generalized concepts, knowledge and research techniques to the classroom and teaching laboratory in a new composites processing, design and manufacturing course sequence that will be offered to both graduate and undergraduate students, preparing them to compete well in the global job market.

Mr. Chairman, the Science Committee has been a strong advocate for better cooperation and collaboration between private industry and the academic community. NSF shares this goal. We also feel that research in the area of automotive technology is a natural avenue for industry and university cooperation.

As a result, NSF staff have begun to work informally with representatives of Chrysler, Ford, General Motors and other manufacturing companies to explain the merit review process, expose the university research community to PNGV-related technical issues, broker matches between industry experts and university researchers and encourage the participation of manufacturing industry experts in the review of research proposals. An NSF/DoE conference on "Basic Research Needs for Vehicles of the Future" was held in January, 1995, in partnership with major U. S. automobile manufacturers and their suppliers. 188 participants, from 34 different U.S. universities, 18 government agencies and 24 different companies in the automotive industry, worked together for three days to define the key research problems in the six most critical long-term research areas defined by the research staffs of Chrysler, Ford and GM. A follow-on conference in January, 1996, on "Basic Research Needs for Environmentally Responsive Technologies of the Future" identified industry-specific basic research opportunities in five industries, including the automotive industry. A third conference is being planned for late 1996 or early 1997 to focus on long-term engineering research issues relevant to PNGV.

The dialogue between the automotive industry and university researchers has already had positive effects. For example, NSF is negotiating a new five-year award for an Engineering Research Center (ERC) at the University of Michigan which can be considered an investment in PNGV research goals. This center was one of four new ERCs selected in competitive merit review from among more than 100 candidates in FY 1996. It brings Chrysler, Ford, GM, Caterpillar, General Dynamics, Boeing, United Technologies and 24 of their technology suppliers together with a team of university researchers to develop a new generation of low-cost machining systems that can be easily reconfigured to increase the flexibility of automotive, heavy vehicle and aircraft production. The ERC's research and education agenda directly and specifically addresses the long-term needs of three related industry sectors: Aerospace, Heavy Vehicles and Automotive end users. The companies representing the industry supplier base that have joined this ERC effort are focused on Controls (7 members), Sensors (5), Machine Tool Builders (9) and Tooling (3). NSF also supports the Materials Research Science and Engineering Center (MRSEC) at Michigan State University, a partnership between Michigan State, Chrysler, Ford and GM established by NSF in 1994 to provide a focal point for fundamental research on materials and devices with high potential for application in vehicular sensing systems. Eleven NSF-supported Industry-University Cooperative Research Centers (I/UCRC) have attracted membership by the major U. S. automobile manufacturers because of their focus on research themes consistent with the long-term interests of these companies.

It is also important to point out again that all these NSF projects were awarded through a competitive merit review process in which there was no targeting of technology areas by NSF. Nevertheless, the range of technical topics covered among the proposals NSF receives correlates well with PNGV emphasis areas. Leadership from the federal government, in partnership with industry, is having an impact on how the long-term research needs of U. S. industry are made known to the academic community. This in turn influences how academic researchers plan their own individually-conceived research and education goals.

In conclusion, Mr. Chairman, I would like to thank you for holding this hearing on the PNGV program and hope to work with you and the Committee to help foster greater cooperation between the university research community and private industry, especially in the area of automotive research and development.

Thank you.

Mr. EHLERS. Thank you very much. Just one quick question for clarification again. The money from PNGV that goes to the NSF, is all of that funneled through your office, through your directorate, or does some of it go to other areas?

Dr. BORDOGNA. There are other directorates, primarily math and physical sciences, engineering, some social behavior, economic science and computer engineering. The major portion is in math, physical science and engineering.

Mr. JOHNS. Excuse me, sir, but that money is not PNGV money sent to NSF. That's out of NSF's budget itself.

Dr. BORDOGNA. I didn't understand the question. The $54 million is in the regular NSF budget and is spent out in those directorates for individual proposals and we grant them.

Mr. EHLERS. Good. Thank you for the clarification. I appreciate that.

We've also been joined by Congresswoman Sheila Jackson Lee. We're happy to have you with us.

Finally in this panel is Mr. Thomas Gross from the Department of Energy.

Mr. Gross.

STATEMENT OF THOMAS J. GROSS, DEPUTY ASSISTANT SECRETARY FOR TRANSPORTATION TECHNOLOGIES, OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY

Mr. GROSS. Good afternoon, Mr. Chairman and Members of the Subcommittee. I thank you for inviting me today to appear to discuss the Department of Energy's role in implementing the Partnership for a New Generation of Vehicles.

I would like to request permission of the Chair to enter my complete written testimony for the record.

Mr. EHLERS. Without objection, so ordered.

Mr. GROSS. With respect to transportation fuel, the situation does seem to be a little bit more subtle than it was a couple of months ago. Supplies of gasoline are plentiful and U.S. drivers are paying less at the pump than during the short-term price run-up earlier this year, and prices are projected to continue their downward trend for the remainder of the summer.

However, we ought not to be lulled into complacency. The rise in gasoline prices, which evidently resulted from a coincidence of several unrelated events, may be a warning for the future. To me the Partnership for a New Generation of Vehicles is about heeding that warning.

We in the United States are consuming over 17 million barrels of petroleum each day, one quarter of the world's total. As Mr. Johns has also pointed out, about half of the oil that we use, nearly nine million barrels per day, is imported. About two-thirds of our total consumption is used to meet our total transportation demands.

With consumption growing at over one percent a year and domestic production declining by 1.4 percent annually, the Energy Information Administration predicts that by the year 2000 imports will make up 56 percent of our consumption and will exceed 60 percent by 2010. Imported oil represents a significant transfer of wealth, about a billion dollars a week going out of our country in 1995.

Adding to the concern I would note two other forecasts. The rapid growth of economies of the world's developing nations, particularly in East Asia where economies are growing at 8 to 12 percent per year, lead to forecasts of substantial growth in world oil demand, growth which could easily outstrip the ability to respond with inexpensive supplies.

Second, by 2010 two-thirds of the oil traded on the international market will come from the Persian Gulf, a region of persistent political instability. While we can only speculate on what will trigger the next petroleum price shock, forecasts of supply and demand suggest it's a good bet that there will be one, and the Members of the Subcommittee certainly realize the economic impact of a petroleum price shock. In the last 20 years, significant rises in the price of petroleum have each been followed by a recession.

With its programs directed at more energy-efficient and alternatively fueled vehicles, the Department of Energy is seeking to address concerns related to rapidly growing worldwide petroleum use as well as concerns about the emissions resulting from fuel combustion.

Vehicle efficiency improvements since the 1970s have been offset by increases in population, vehicles and per capital miles driven. The result is that total U.S. consumption of gasoline has risen about one and a half percent per year over the past 20 years. Low gasoline prices continue to encourage us to drive more and to purchase less fuel-efficient vehicles, such as sport utilities and light trucks which now account for about 40 percent of domestic vehicle sales.

One approach to reducing our demand for oil would be to raise the cost of gasoline through taxes. Some argue that another would be to increase automotive fuel-efficiency standards. The value of PNGV is that success in developing cost-effective technologies that achieve radically improved fuel economy could reduce demand for petroleum without resorting to such government control and command measures.

This opportunity and its clear alignment with the Department's mission objectives of reducing our reliance on imported oil, increasing the efficiency of energy consumption and reducing the pollution resulting from energy use prompted the Department of Energy to be an active partner in striving to achieve the goals of the Partnership for a New Generation of Vehicles.

Through the Offices of Energy Efficiency and Renewable Energy, Defense Programs and Energy Research, DOE has been an important player in PNGV, providing the majority of federal resources supporting work which is directly relevant to PNGV's goals. For 20 years we've been working in partnership with the automakers and their suppliers to developer cleaner, more fuel efficient cars for America and the world to use in the 21st century. PNGV has helped further focus this effort within the Department of Energy.

Our funding is primarily directed at higher-risk enabling technologies that industry would not be expected to undertake on its own. Our activities form the backbone of PNGV's effort to reach the 80-mile per gallon goal. The unique resources and capabilities of 12

DOE national laboratories are being brought to bear and have played a major role in the early successes of the partnership.

Though we are only three years into the program, we have already had substantial and measurable progress. As Mr. Johns noted, you've received copies of a report compiled by the automakers known as PNGV Technical Accomplishments. This report details some of the breakthroughs born of our collective efforts. I would just like to point out that it also mentions of the 65 projects and programs that are identified in the report, that 50 of them have involvement from the Department of Energy national laboratories.

For further details I would call your attention to pages 6 through 8 of my written statement, from new and more efficient catalytic converters to high-tech casting processes to smaller, more effective air bags to tires with improved rolling resistance. As you can clearly see in the report, DOE and its laboratories are making initial contributions to achieving PNGV's objectives.

But our ultimate goal is successful development of technologies that enable production of pollution-free transportation vehicles with very high fuel use efficiency and which are fueled by cheap, inexhaustible renewable resources. Full accomplishment of PNGV's challenging goals ideally within the original time frame, but certainly at some point, is vital to securing this result for future generations.

Thank you for the opportunity to appear, and I'll be happy to answer any questions.

[The prepared statement of Mr. Gross follows:]

Statement of

Thomas J. Gross
Deputy Assistant Secretary for Transportation Technologies
Office of Energy Efficiency and Renewable Energy
United States Department of Energy

Before the

Subcommittee on Energy and the Environment
Committee on Science
United States House of Representatives

July 30, 1996

Mr. Chairman and Members of the Subcommittee:

Thank you for inviting me to appear before you today to discuss the Department of Energy's role in implementing a ground-breaking initiative--the Partnership for a New Generation of Vehicles (PNGV). This partnership was born of a **vision** shared by the Administration and the leaders of Ford, Chrysler and General Motors to join the resources of the Federal Government, its laboratories and university based research institutions together with those of the major automakers and their supplier networks, to pursue three aggressive, interrelated R&D **goals**:

- develop manufacturing techniques to reduce the time and cost of automotive design and production;
- improve fuel efficiency and emission performance of existing powerplants; and
- develop a new generation of vehicles with triple the fuel economy of today's mid-size cars while maintaining or improving comfort, safety, performance, emissions and price.

In my remarks today, I will focus on some of the most significant points, from the Department's perspective, regarding PNGV:

- This initiative addresses crucial areas of national interest,
- PNGV is directly aligned with the Department of Energy's mission,
- DOE participation is critical to its success, and
- There is ample evidence that this new approach is working well and producing significant results; it has bolstered and reinforced an already developing partnership between the Department and the U.S. automotive industry.

I will also address some of the technical and resource challenges we face as we pursue its goals.

PNGV IS IN THE NATIONAL INTEREST

Currently the United States consumes over 17 million barrels of petroleum each day. This is about 25 percent of the world's total consumption, yet the U.S. has less than 5 percent of the world's population. Imports supplied about 50 percent of U.S. domestic consumption in 1995. With consumption growing at over 1 percent a year and domestic production declining by about 1.4 percent annually, the Energy Information Administration predicts that by 2000 imports will account for 56% of our consumption, and will exceed 60 percent by 2010. With this comes a significant transfer of wealth - reflected in the balance of payments. For 1995 the net transfer totaled just over $48 billion for crude oil and petroleum products.

By 2010, two-thirds of the oil traded on the international market will come from the Persian Gulf, a region of persistent political instability. As Daniel Yergin observed in his book *The Prize*, oil is a major factor in geopolitical struggles. Additionally, the rapid growth of economies among the world's developing nations, particularly in east Asia, means competition may greatly increase for petroleum on the world market. As living standards and mobility increase, and economies achieve desired growth, substantial growth in oil demand is forecast-- growth which may outstrip the ability to respond with inexpensive supplies. To the extent this occurs, increased global demand could lead to higher real energy prices in the United States, especially for oil.

Two thirds of the petroleum consumed in the U.S. is for transportation. Vehicle fuel efficiencies have shown steady improvement since the 1970s, but increases in population and per capita miles driven have more than offset these gains, causing total consumption of gasoline to rise by about 1.5 percent per year over the past 20 years. Still, cheap gasoline prices are encouraging us to drive more, and to purchase less fuel efficient vehicles such as sport utilities and light trucks, which now account for nearly 40 percent of domestic vehicle sales. One approach to reducing demand would be to raise the cost of gasoline through taxes, as many European countries and the Japanese have done. Some argue that another would be to increase mandatory fuel efficiency (CAFE) standards. **The value of PNGV is that success in developing cost-effective technologies, that achieve radically improved fuel economy, could reduce demand for petroleum without resorting to such government command and control measures.**

PNGV success would contribute in another area of national interest: the environment. Americans clearly value a cleaner environment; as a nation, we have made tremendous strides in improving the quality of our land, air and water during the last two decades. However, the Environmental Protection Agency reported in October of 1995 that 134 million Americans live in areas that do not meet the National Ambient Air Quality Standards. For 45 million citizens, non-attainment is directly attributable to transportation emissions. In urban areas 80 percent of the pollution comes from energy used by transportation systems, and the American Lung Association estimated in 1988 that Americans spend $50 billion annually on health care resulting from air pollution. The Association is currently updating this estimate and has indicated that the cost today is considerably higher, not only due to rising health care costs, but also because understanding of the impacts of particulate emissions on the human body has dramatically improved. Transportation is responsible for 78 percent of the carbon monoxide, 45 percent of nitrous oxides, about one third of the volatile organic compounds and carbon dioxide, and 27 percent of the particulates. With concentrations of carbon dioxide 25 percent higher than in pre-industrial levels, the global potential for energy use to contribute to climate change has emerged as a new environmental risk. Increased atmospheric concentrations of greenhouse gases are likely to alter earth's climate system, although scientists do not agree on the timing and nature of potential climate changes, or on the scope and severity of the problems associated with a changing climate system. The widespread use of vehicles with substantially higher fuel efficiency and alternative fuel capabilities, one of the PNGV's major goals, could result in considerably lower emissions per mile driven, thereby contributing to greatly improved air quality.

DOE HAS A CRITICAL ROLE IN PNGV

The Department of Energy, through the Offices of Energy Efficiency and Renewable Energy, Energy Research, and Defense Programs, is an important player in all levels of PNGV activity. While the lead agency is the Department of Commerce, the Department of Energy is contributing the majority of the total federal spending for work directly relevant to PNGV. This funding is primarily directed at higher risk research that industry would not be likely to undertake on its own, and which forms the backbone of the PNGV Goal 3 effort. Twelve DOE laboratories are among the 20 federal laboratories whose capabilities have been identified as essential to the PNGV effort.

DOE also plays a leadership role in PNGV. The Assistant Secretary for Energy Efficiency and Renewable Energy is an active member of the Operational Steering Group. The Director of the Office of Advanced Automotive Technologies serves as Vice-chair of the PNGV Technical Task Force Executive Committee. Scientific staff from DOE and its laboratories predominate among government members of the technical teams that identify technical targets and develop the roadmaps used to direct research. Membership on these teams is based solely on technical ability and experience.

The results of DOE support for research and development can be seen in the PNGV Technical Accomplishments report recently published by the United States Council for Automotive Research (USCAR). Three quarters of the developments deemed significant enough for inclusion in this document were achieved in partnership with the Department of Energy community.

Participating in an undertaking of this magnitude and national importance has led the Department of Energy to undertake some healthy self-examination, resulting in improvements in the way we manage projects and interact with other agencies and the private sector. Within the Department of Energy we have recently reorganized the Office of Transportation Technologies to bring nearly all of the department's PNGV projects under the direction of a single office, the Office of Advanced Automotive Technologies. This move was designed to streamline management of PNGV projects, and to facilitate direction of resources to the most promising technical areas.

We created the Clean Car Coordinating Committee (C-4), initially composed of technical representatives from each of the 12 DOE laboratories, to help coordinate laboratory support of PNGV, and to better identify for industry where in the DOE community specific technical expertise resides. The Committee has since been expanded to include representatives from the eight other Federal laboratories now supporting PNGV, providing an example of what should become a growing trend among Federal agencies - - coordination and leverage of resources toward the solution of complex problems.

In partnership with Chrysler, Ford and General Motors, DOE sponsored the first phase of the FutureCar Challenge, which was completed in June, 1996. Designed to stimulate innovation by the next generation of engineers, the FutureCar Challenge is the most ambitious student vehicle competition to date. Twelve university teams from across the nation were each given a new mid-size production vehicle and free reign to modify the car to meet PNGV's goals. The DOE is proud to sponsor the FutureCar Challenge because it provides students practical, hands-on, engineering experience and a chance to be creative in seeking solutions to some very difficult engineering problems. The students' accomplishments so far have been truly impressive.

Coordination of resources has increasingly become a concern for the federal side of the PNGV effort. Our fiscal year 1996 budget request for this initiative was cut significantly. Based on House and Senate budget marks for 1997, we will lose further ground next year relative to the budget levels we had initially identified as necessary to accomplish PNGV goals. It is important that we continue to demonstrate our commitment to this initiative, and to the idea that the government can be counted on as a partner with industry in multi-year, high-risk efforts.

We are concerned about funding reductions adding additional levels of risk to the PNGV effort. And it is important to note that, partially in response to PNGV, governments in Japan and Europe have formed similar R&D partnerships, to which they have committed considerable resources. We know that they are pursuing similar lines of research activity, and that resource commitments from their governments are growing. If these trends continue, they may reach the world market before we do, and the United States may well be importing the automotive technologies of the future--just the opposite result of the vision originally associated with PNGV.

MISSION ALIGNMENT AND TECHNICAL BARRIERS

Major mission responsibilities of the Department of Energy include:

- Enhancing energy productivity to strengthen the United States economy and improve living standards,
- Ensuring reliable energy services with reduced vulnerability to energy price and supply volatility, and
- Reducing adverse environmental impacts associated with energy production, delivery and use.

All three of these fit well with the goals of PNGV.

Within the Department's transportation programs, one of our two primary objectives is to help achieve a radical improvement in transportation fuel efficiency--a critical component in our nation's effort to stem the rising tide of oil imports. I'd like to take the next few minutes to outline what we at the Department of Energy see as some of the most challenging technical barriers to accomplishing this objective.

Propulsion Systems

Propulsion systems that more efficiently convert fuel to useful power, with the lowest possible emissions, are a major barrier. Several options have undergone considerable development but require further R&D to improve critical performance parameters such as part-load efficiency; transient emissions; noise, vibration and harshness (NVH) characteristics; low weight; small packaging volume; and 100,000-mile maintenance-free reliability. Challenging goals must be met in all of these areas with technologies which are low in cost and manufacturable in high volumes. The options which have been seriously considered include diesel cycle engines, gas turbines, and fuel cells; other thermal engines (e.g. Stirling, Miller cycle) could become serious candidates with the right breakthroughs.

Hybrid Vehicles

For successful hybrid vehicle systems, two critical technical barriers relate to energy storage and power electronics. High power energy storage devices are needed to augment power from the main propulsion system for acceleration and hill climbing, and for recapturing energy during braking. The storage unit must be thermally managed and have high specific *power* in contrast to the high *energy* requirement of batteries for electric vehicles. Furthermore, the power electronic interfaces that direct power flow between components need further development. Today's systems are too heavy and large to be efficiently packaged in a vehicle. Work is needed to reduce the size, weight and cost, and to manage the thermal loads. New technologies are needed to support high voltage and current power handling equipment planned for these propulsion systems. Remaining drive line components need to be optimized with respect to efficiency, performance and cost.

Advanced Materials

One of the most practical ways to increase fuel efficiency is to reduce the weight of the vehicle. Achieving the goals of PNGV will likely require reductions in a vehicle's weight of up to forty percent. Adding more components with world class reliability standards, at comparable costs, while reducing weight and maintaining safety, is extremely challenging, but is essential to improving fuel efficiency. These savings can be realized if aluminum or other light-weight materials can be successfully substituted in the power unit, the power electronics, electric drive system, vehicle chassis and related components. Weight savings must be sought not only through material substitution but through better integration of propulsion system components and vehicle structural elements.

Fuel Cells

Proton exchange membrane fuel cells, which produce electricity by efficiently combining hydrogen and oxygen, offer the greatest long-term potential fuel economy gain, but require by far the most demanding technical improvements. Some of the key barriers to commercial fuel-cell powered vehicles include:

- Improving the performance and reducing the cost and weight of key components including bipolar plates, membranes and catalysts.
- Demonstrating full-sized, fuel-flexible, integrated fuel processing systems and

components. These should be based on advanced catalysts and reactor processes and designs that demonstrate the required operating characteristics and efficiency for automotive applications.
- Developing more compact, higher pressure storage systems for hydrogen that use less expensive materials and fabrication processes.
- Improving the system's tolerance to the presence of carbon monoxide in the hydrogen-rich fuel, which will greatly simplify the system and reduce cost and weight.

These are a sample of the difficult technical challenges we are addressing.

RECENT ACCOMPLISHMENTS

I have previously mentioned the recent compilation of technical accomplishments that support the three goals of PNGV. Following are highlights of several recent accomplishments that demonstrate the scope of DOE's activities supporting PNGV.

- Recently, a cost-shared project between General Motors and DOE produced the nation's first successful proton-exchange membrane fuel cell system powered by methanol. Fuel cells are a prime candidate to meet PNGV's 80 miles per gallon goal; they have exceptionally high fuel efficiency combined with ultra-low emissions. Though likely beyond PNGV's time horizon, hydrogen-powered fuel cell technology offers the promise of fuel conversion efficiencies consistent with vehicles which get up to 100 miles per gallon.

- Researchers at Argonne National Laboratory have developed a quick-starting system to convert liquid methanol fuel directly into hydrogen. Methanol is an attractive alternative source of fuel for an automotive fuel cell because it can be produced from domestic resources such as natural gas, coal or renewable biomass. The new system is compact, lightweight, and operates on oxygen taken from the air. The system's startup times have met PNGV's target rates.

- A team from Ford and DOE's Lawrence Livermore National Laboratory has made dramatic improvements in high-pressure tanks to store hydrogen gas for automotive applications. Hydrogen-fueled vehicles require on-board hydrogen storage capable of containing a large volume of gas for extended periods. The new tanks are formed from lightweight composites and use a laminated metalized polymeric bladder, which should be lower in cost than conventional tanks and have a longer life.

- Working under a cooperative research and development agreement, an industry/laboratory team, including five DOE laboratories, developed a new catalyst for automobile catalytic converters that substantially reduces emissions of nitrogen oxides. Use of the new catalyst will allow engines to operate with a leaner burn, thus providing improvements in fuel economy. The new catalyst may also enable wider use of diesel cycle engines.

- A team from General Motor's Delphi Saginaw Steering Systems and DOE's Sandia National Laboratories developed an "intelligent" system for induction hardening steel auto parts. In this case, advanced technologies developed by DOE to achieve materials hardening requirements for weapons were determined to have automotive applications as well. The new process, which is now producing components for Saturn cars, provides parts with greater quality control and uniformity.

- In early July, 1996, a team from Thompson Aluminum Casting, near Cleveland, Ohio and Oak Ridge National Laboratory announced a major breakthrough in compression-forming of cast aluminum. This breakthrough combined the unique supercomputing modeling capability at Oak Ridge and the innovative casting ability of Thompson Aluminum. The new technology produces cast aluminum parts with the properties of forged aluminum, but at a fraction of the cost. General Motors plans to use 400,000 of the new, lightweight parts to replace heavier cast iron components in its 1998 vehicles.

- Tapping into forty years of national laboratory experience in developing and packaging high-performance, lightweight parachutes for military applications, Precision Fabrics Group, Incorporated, of Greensboro, North Carolina has developed a revolutionary new airbag design that may result in safer automobiles. The new design is about 60 percent smaller when folded and weighs 60 percent less than a conventional airbag. The smaller size means the airbag inflates faster. *Popular Science* selected this project for one of its "Best of What's New" awards.

- A team of researchers from Trinity Flywheel Batteries in San Francisco, California, General Motors and DOE's Lawrence Livermore National Laboratory has made significant advances in the field of flywheel energy storage. High-power energy storage is a critical technology for hybrid vehicles. The team's recent accomplishments include new fabrication methods using composite materials, simple and durable rotor designs, a new high-power permanent magnet motor/generator system, and a successful lab demonstration of an integrated flywheel system. In addition, Trinity demonstrated the first successful containment of a rotor burst using a compact structure.

- A cost-shared cooperative research and development agreement between Oak Ridge National Laboratory and the domestic automakers' Automotive Composites Consortium is currently addressing the adhesive bonding of dissimilar materials such as aluminum, plastic composites, and steels. Increased use of such lightweight materials will be required to meet PNGV's goal. The industry/laboratory team has developed standardized test methods and computer models for bonded joints, tested the strength of adhesive joints, and developed a new method of surface treatment that provides stronger joints. The University of Texas is also a contributor to this project.

- It is estimated that four to seven percent of a car's highway fuel consumption is lost just in overcoming the tires' rolling resistance. A team from Goodyear Tire and Rubber Company and Sandia National Laboratories has perfected advanced computer modeling tools to help design tires that will save energy while preserving other key tire performance characteristics. Tires designed using the new tools may be in production within three years.

- General Motors successfully converted a 1995 Lumina sedan to serve as a hybrid test vehicle. All propulsion system components were completed for a first-generation vehicle, including battery, traction motor, inverter, thermal management, electric power steering, regenerative brakes, and control system. This project, cost-shared at 50% each by industry and government, will develop hybrid propulsion systems with twice the fuel economy of today's vehicles. Parallel cost-shared contracts are also in place with Ford and Chrysler. In total, about 25 separate companies participate in the three contracts.

- The Department of Energy has placed a new emphasis on advanced diesel-cycle engines for hybrid vehicles. Diesels are the most efficient internal combustion engine and thus are a leading candidate for meeting PNGV's eighty miles per gallon goal--a point clearly recognized by the National Research Council's committee to provide peer review of PNGV. The objective of this four-year cost-shared program is to provide a viable diesel option for PNGV's hybrid propulsion systems. Our goal is to develop a clean-burning engine with a brake thermal efficiency of forty-six percent. Major partners, in addition to the engine industry, include national laboratories, universities, and suppliers.

- In June, 1996, *R & D Magazine* awarded one of its coveted "1996 R & D 100 Awards" to the National Renewable Energy Laboratory and Benteler Industries of Grand Rapids, Michigan, for developing a vacuum-insulated catalytic converter that reduces emissions when a car is first started up. In recent tests, the new converter reduced hydrocarbon emissions by 84 percent and NOx emissions by 50 percent.

- Researchers from Cummins Engine Company, of Columbus, Indiana, and DOE's Combustion Research Facility at Sandia National Laboratories in Livermore, California, have greatly improved knowledge about combustion in diesel engines. Using a special engine fitted with quartz windows and advanced laser diagnostics, researchers for the first time can see exactly how fuel mixes with air in the combustion chamber, how it ignites and burns, and how soot and oxides of nitrogen are formed. Knowing where and when soot and NOx form during combustion helps industry design cleaner, more efficient engines.

These are just a few examples; there are many others. However, the key point is that DOE's programs are making substantial progress toward our goals, as well as the goals of PNGV. To achieve these goals, it will be important to continue working in close partnership with the auto industry and suppliers to leverage resources. Cooperation among the federal government, industry, and DOE's national laboratories on high-risk research and development of vehicles holds out the promise of a dramatic reduction in America's dependence on petroleum, with concomitant improvement in public health.

In summary, the PNGV addresses crucial areas of national interest; DOE will continue to be an important player in the Partnership for a New Generation of Vehicles; and PNGV is a high priority program within the Department of Energy. However, DOE's focus goes beyond PNGV to encompass longer range, higher-risk technologies that may not be commercially viable in PNGV's time frame. These advanced technologies will ultimately be critical to breaking our dependence petroleum and securing clean, energy-efficient transportation for future generations.

Thank you for this opportunity to appear. I will be happy to answer any questions.

Mr. EHLERS. Thank you very much, Mr. Gross.

I will begin with several rather broad questions. As I mentioned in my opening statement, one of the concerns has to be why should taxpayer money be used for this project, and that question has become particularly relevant in the last few years as we've engaged in a dramatic effort to achieve a balanced budget.

The costs have been pointed out. The federal expense there is in the neighborhood of $300 million per year overall and that's a large amount of money. A few years ago that didn't seem that large in the federal budget. Today it seems like an overwhelmingly large amount of money. So there is going to be substantial Congressional concern about that.

I was intrigued with your comments, Mr. Gross, about future petroleum supplies. I wish the rest of the citizens of this nation were fully aware of that and willing to accept those numbers because it's a great danger, and I know Dr. Bartlett and I have talked about this as well, that the diminishing petroleum supplies have to be a major concern for our nation in the not too distant future.

The question is, how can we as a nation with these stringent budget times manage to continue this sort of research that's extremely important. We have to get away from our dependence on foreign oil and perhaps our dependence on petroleum products and how best to achieve it, and that's what the project is all about.

The question is, can we assure some stable source of funding for this work? And an immediate answer comes to mind, which is highly unpopular politically, but that is to use a portion of the petroleum tax to fund research on reducing the use of petroleum. Most of you are scientists and you know precisely what is meant by positive and negative feedback loops, and you want the right kind of feedback so that you in fact solve the problem and not exacerbate it.

I'm at a loss to identify any other well-defined sources of revenues that we are not using now, but I would welcome your comments on that, and particularly your comments from any one of you on how we can ensure stability for this program because, left to the whims of the Congress, this program is going to face an uncertain future. And the question is, how can we provide some stability to the program because you do not achieve results from programs of this sort in six months or a year or even three years. It has to be a long-term sustained effort. And if you don't have that long-term sustained effort and a commitment so that researchers know that the money is going to be there in the future, you really limit the success of the program.

Just going down the line, Mr. Johns, we'll start with you again and see what comments you might have on this issue, whether the proposal to tax petroleum either at the pump or as it lands on shore so it applies only to foreign oil is one option, but there are many others, and even aside from funding options are there ways that one can assure the stability of the program?

Mr. JOHNS. Well it's really a fairly narrow choice in the sense of the price of fuel, of course, is the way we in a market economy would send a signal. If the United States had a tax equal to the lowest tax of the industrialized nations we wouldn't have a deficit, if we had a tax on our gasoline that was lower than the lowest industrial nation. That would be a very large signal, but it seems like most politicians or former politicians that propose that as a solution because the American people just don't understand why that should be the case, that the market does not know how to discount the value of an unknown remaining resource, as the economists would say. So the political option just isn't there to do that.

The second, of course, is to set CAFE standards or their equivalents and slowly tighten the screws, and that drives the auto industry apart from the marketplace. It would cause them to make changes to automobiles that they may well not be able to sell. So there is a limitation as to how far one can go in that direction.

And, finally, there is, as the Proverbs would say, a vision in the notion that if we can set technological goals that we can work together using the federal R&D enterprise and the private sector enterprise to solve these problems, then in effect the problem becomes irrelevant.

If you think about 80 miles to the gallon, and today we are nominally in a fleet getting 26, that means you could have three times the size of the fleet and no increase in the amount of fuel consumed or imported. So it is really a dramatic achievement.

I would also like to comment that the amount of gain was intentionally chosen to tax the far end of a fossil fuel burning machine in order to drive us towards solutions that aren't just saving oil, but shifting from oil, and hydrogen and other interesting prospects are very much part of the R&D goals here. So it's important.

If I can make a clarification. Your third panel with Mr. Jones, who is the Chairman of the Peer Review Group of NRC. He is not part of the management in the federal establishment. He leads the peer review group that will be following in your third panel, just by clarification.

Mr. EHLERS. Thank you. I appreciate that. He's listed here as the Chair of the PNGV Standing Committee.

Mr. JOHNS. It is a Standing Committee of the NRC because we wanted annual review, annual peer review. So it is a standing rather than an ad hoc committee. That's the reason.

Mr. EHLERS. Thank you.

Mr. Chapman.

Mr. CHAPMAN. Sir, you asked almost rhetorically why the government should be caught up in a research program when the car companies today appear to be so prosperous, and there of course have been times past, in the late '50s and early '60s, when the car companies were very prosperous, and then subsequently they were in dire straits because other forces, technological and others than those interposed themselves.

The government's role in the program is, as just about every one of these speakers have said, is to engage in the long-range, high-risk research and, as you pointed out, that sort of research is best nurtured in a very stable climate. We have suffered a decrease in every request we've made where funds are related to PNGV, and the most recent was a $60- to $70 million cut in the '96 budget. So the obvious answer to your question is the very point that you made, that at least funding stability through the life of the program would do wonders for the research project.

Mr. EHLERS. Do you have suggestions on how to provide that stability of funding?

Mr. CHAPMAN. That's more on your side than ours, but we certainly try to make the case every time that we would want a stable level of support.

Mr. EHLERS. Thank you.

Dr. Bordogna.

Dr. BORDOGNA. I guess NSF's task here is at the intellectual stability end. When we enter into partnerships our task usually is at the discovery end of things. We pick out investments in those areas that will lead the partnership ahead, but it will create new knowledge and will educate a work force.

The Engineering Research Center at the University of Michigan, the new one, for example, these are 11-year endeavors. They're checked periodically to make sure they sustain the quality for which the award was given, but there is a commitment here over time now for some focus on research areas jointly defined by the PNGV group.

How NSF could influence a greater investment in this part of the activity depends on how NSF can influence both the President and the Congress that investment in this kind of work is important for the future of the nation.

I do want to emphasize that NSF's role basically is for the discovery of knowledge related to the needs, but also the education of the work force. An Engineering Research Center, for example, is as much an educational paradigm as it is a research paradigm. So the future work force to keep things going is important there.

Finally, the partnership we're trying to synergize generally between industry and academe, this is part of this, and it's a focused one. That hopefully has momentum to carry on and have an influence on the amount of resources invested by the taxpayers. So I think the flavor of NSF is in that regard.

Mr. EHLERS. Thank you.

Mr. Gross, do you have anything to add?

Mr. GROSS. Well let me see if I can add a thought or two to what has already been put before you. It has already been pointed out that the costs to the consumer, the full costs associated with the energy situation worldwide and perhaps the environmental situation as well are not completely reflected in the costs that people are paying for fuel, and as a result we have this tremendous dependency on a single fuel, which in the United States is diminishing in supply. As a result of that, the customers of the automotive industry's products do not put very much emphasis on fuel economy and much less emphasis than they did a few years ago as a matter of fact.

So industry is going to continue to make its big profits by responding to its customers, and I'm sure that the industry panel will talk about that in more detail. As a result, the work that would be needed to avoid a surprise to the customers, which is probably going to happen in, we don't know, three years, five years or 15 years, is going to have to be supported some other way so that the advanced technologies which will reduce that dependency are available at that point in time so that we can have a more rapid reaction to the situation. That's why I think the government needs to have a key role.

In terms of stability, I think unless we have enough dialogue so that the public generally begins to understand that situation better, as you pointed out, and between the Administration and the Congress hearings and other sessions where we can compare our views, then it will continue to be difficult to get the stability that we're going to need to be successful.

Mr. EHLERS. Thank you.

We will next recognize the Ranking Member for his round of questions, and after that we will proceed down the remaining Members in the order in which they arrived at the Committee.

Mr. Roemer.

Mr. ROEMER. Thank you, Mr. Chairman.

Again I apologize for being a little bit late to hear all of the opening panel's statements, but in reading my material prior to this hearing I couldn't help but be caught up in some of the cynicism and the skepticism out there when this was first put together about whether or not the goals were achievable and whether or not we should try to shoot for 80 miles per gallon or 100 miles per gallon or some of the other ambitious goals that have been set forward.

I thought about it and I couldn't help but think as we watched the Olympics and if we go back in Olympic history and we see four decades ago nobody thought that people would jump over 27 feet, and Bob Beamon did that. Prior to these Olympics, nobody thought that the women gymnasts had a chance at a Gold Medal as a team, working together as a team and what this country could achieve, and we did that. Certainly nobody gave Carl Lewis much of a chance to repeat with his fourth Gold Medal last night, and he did that.

When I hear so many accusations out there about corporate welfare on this particular program I think I reached some of the same conclusions there. Now I understand that we have a budget deficit, and I am one who proposes cutting programs that are not working very well, but I certainly think that this one is more in the interests of a proactive private partnership working together with our government and our businesses to invest in what we can achieve in the future.

Mr. Chapman, can you respond to just some of the skepticism about, you know, is this corporate welfare or is this the kind of proactive private and public partnership that we need to do in the future, to pool our resources and work together as a country?

Mr. CHAPMAN. Well, sir, we're very sensitive to the fact that this is the first time this has been done this way, and it has not been necessarily an easy road to get things aligned as we would like, but nevertheless we have been operating, industry and government partners with integrated technical teams addressing the individual technologies for the program.

Just as an observer I would say that the people that are caught up in this clearly believe that they are riding the wave of the future and that they are missionaries for something that absolutely must happen.

And I think, as you've heard before, at the executive level of these companies there is great support on the basis that their view is that we're addressing important national goals and an alternate of the old command and control approach on the part of the government that makes things very difficult.

I would add another personal note that a year ago on the 5th of July I was requested, and gave, a presentation to a committee of the European Commission in Brussels. The workshop was on the "Car of the future," and then it was described as being the largest gathering of people of this sort on any subject.

Clearly I, in describing in PNGV, was a person of great interest on their part, and the questioning at the time and the questioning after had the flavor of, "Oh, here you guys go again. First, you went and you moon shot, and now you're marshalling the total resources of the government, and if we Europeans don't get with it, you're going to be a generation ahead." And I think I truly believe that.

If we're successful with regard to our fuel cells and our flywheels and our ultracapacitors and the things that we're working on to integrate these, we being the team now and the industry, we truly will be a generation ahead of the international competition. That's a very powerful position to be in with regard to our competitiveness, the jobs that will be created and so on, and to do that of course, as we've said, it's a long-range research project, and we need steady, consistent support to bring these sorts of things in.

Mr. ROEMER. That's just what I wanted to hear, Mr. Chapman, and I hope I wasn't leading you to that answer.

Mr. Johns, just a quick question for you, and then any time I have left over I would like to yield in addition to Ms. Rivers' time when it's her turn because I think she has a great deal of interest in this subject.

There is going to be a witness that comes before us in the next panel that has some concern about the level of attention given to pollution prevention in this program. Should reduced emissions be one of our highest priorities?

Mr. JOHNS. In this country we have a number of cities in the summertime that are out of compliance for air quality. What this means of course is greater health bills and people dying as a result of this environmental burden. It's a very important part of the goal if you think about just what might be accomplished in other cities of the world, Europe in particular, but also increasingly in Asia.

Our prosperity is not selling cars to more Americans. America is not growing that fast and we have a lot of automobiles. Our prosperity is dependent on selling automobiles elsewhere in the world and with a better technology, and those cities of the world all have increasing air quality problems, pollution problems.

If you had a car that was three times better than any other, you're going to have the world beating a path to your door. It's where real opportunity lies if you look at it from the environmental perspective, the excitement of being able to have twice as many automobiles in the world with half or less of the contribution to the environmental burden.

The automobile is a wonderful piece of mobility that is important to everybody, and you can't take that away from people. What you have to do is provide it in a manner that creates the least burden environmentally. It's one of the most exciting parts of what could be accomplished. If you set out to change, to make the world a better place, a car that is one third as polluting as the cars today would be one of the great goals that you could achieve.

Mr. ROEMER. Thank you, Mr. Johns. I guess if you would have answered that question yes or no or true or false I might have had some time left to yield to the gentlelady from Michigan, and I apologize.

Mr. EHLERS. The gentleman's time has expired.

We will next recognize Congresswoman Rivers followed by Dr. Bartlett.

Ms. RIVERS. Thank you, Mr. Chairman.

There has been a lot of discussion about whether or not we can afford to pursue this project, and I want to ask whether we can afford not to pursue the project, both in terms of our environment and whether or not the earth is warming and the role emissions play in that, and also in terms of our worldwide competitiveness, our industries, and not just the auto industry.

So I would be particularly interested in hearing from each of you how you see this project comparing to what our prime competitors, European and Japanese, are doing as they build their industries and economies and look for a more efficient vehicle.

Mr. Johns.

Mr. JOHNS. I think there are two levels of this. First of all, our economy has become a global economy and our success in our economy and our prosperity is highly dependent on us being a successful global competitor in an advanced knowledge economy of the world. Other nations are less uncertain about the wisdom of government and industry cooperating in the interests of the future prosperity of those nations and their economic strengths. The United States has had a continuing debate over that for some time.

Other nations therefore are a little better organized in order to have that cooperation. The Asian nations, the tigers, as we say, Taiwan and Singapore and so on as well as the Japanese, have aggressive programs in auto efficiency investments. The price of fuel in Europe is of course considerably higher. So the significance of having such vehicles in Europe has not fallen on deaf ears in the European Community, and they also have an aggressive investment program.

I think there are two gains here, but one more subtle. The United States has in the past few years had an adversarial relationship with industry, one with more of a regulatory orientation, and as the auto folks said when they came to town, it was always to be beat up instead of to cooperate on engineering, exciting engineering endeavors. They're enjoying coming to town a lot more these days because of that cooperation. Other nations have gotten past that point.

So that notion of an era of cooperation of the federal R&D enterprise being responsive to our economic needs is I think an important pathfinder in this program, in addition to the fact of our need to do this, or to keep up in a globally competitive world.

Ms. RIVERS. To build on that, Mr. Chapman, given what Mr. Johns just said, what would happen? What would happen to where we are today vis-a-vis our competitors if this program were continued to be cut or would be scaled back significantly, or if we decided to make it a purely private endeavor on the part of the car industries? What would you foresee happening?

Mr. CHAPMAN. Well I would like it if you asked the car people that question when they arrive in the next panel because it fundamentally relates to the business environment.

Before coming to this position I was a Vice President for Government Programs of Allied Signal, which is a company with a lot of people with sharp pencils and green eyeshades, and the position of basic research and long-range research is a tenuous one in today's business climate, and the investment on the part of industry overall in basic research is continually being cut back.

The alternatives, I think, the alternate to this Mr. Johns expressed very well, but I would say that if we are successful in this program in the auto industry, or with this program as a model any industry in the U.S. can count on drawing on the technical resources in our laboratories and facilities, which in lots of cases are unique and not duplicated in industry. We have a bedrock that would keep the U.S., not only the auto industry, but all industries in the vanguard very clearly.

Ms. RIVERS. Dr. Bordogna, to follow up on Mr. Chapman's comments, if you look at our competitors and their willingness to fund basic research and to put dollars into technology that they believe will ultimately pay off, how do we compare? Are we as willing to do that? Are we keeping up with them or are they pulling ahead?

Dr. BORDOGNA. I think we're increasingly willing to make that investment. You have to keep in mind that the end result of all this will lead to fresh wealth which we can tax and share and so on which can get us out of a lot of our dilemmas at the moment. So that's a key issue here, how can we help the nation create this fresh wealth.

The basis of doing that is knowledge, and knowledge can be used in a couple of different ways. One is to make us more productive, and most other nations are really stressing that because you see the productivity of the nations abroad trying to move ahead. But the more important issue for fresh wealth is how can we innovate, how can we take this new knowledge and make something new and different out of it. And Mr. Johns of course makes the point that this is a new and different kind of car which can be competitive worldwide and garner prosperity for us.

The issue here is one again of a classical one that you just can't develop the knowledge in the university and toss it off to industry and it goes down the line. It's a very complicated process and we realize that now and it's not this so-called linear model in how to get at that. It's impossible to get at really how to handle this without some kind of partnership.

So NSF, as one of its four strategic goals is to promote partnerships. An important one we want to promote is a partnership between academe and industry, and the PNGV is a nice venue for focusing on that. What we have here from NSF's point of view is a very specific national need and a national movement in PNGV, but it helps us achieve our more generic end, and that's to create a new, fresh kind of partnership between industry and academe with some government catalyst here that can move us to the new way of doing business. We talk about industries downsizing their labs and so on and they look increasingly to the universities for the new knowledge. We would like to make that partnership really tight.

Ms. RIVERS. Are you seeing spinoff technologies beginning to develop? I mean are we seeing results from this partnership beyond simply moving toward a car?

Dr. BORDOGNA. Generic. From NSF's mission point of view our interest is generic there, to try to work on that, and we're intimate with academe. So our job really should be to try to make that happen well.

The last point I want to make here, going back to the humanity of this, all of our efforts at NSF in discovery and in the research end is a piece of an even bigger issue, and that is to educate the work force. So having this industry/university connection gives the students and the professors a problem-rich environment to look at which can influence the research they do.

Ms. RIVERS. That's interesting because Congress is a problem-rich environment.

[Laughter.]

Dr. BORDOGNA. Well, you know, we want to not just have the professors and students in an ivory tower, but we want to connect them more, and when we do this we're seeing that they're more excited about it. Again the important issue here is that vis-a-vis other nations we're a lot more eclectic in this, we're a lot more yeasty in it, a lot more free ideas flow and competition yields the best grants for the best proposals, and I don't think there is any question that the partnership is important to make us beat the world in that regard, which we do have an edge on.

Mr. EHLERS. The gentlewoman's time has expired. If you have pressing questions we can consider a second round later.

I would also point out that Congress is not only a problem-rich environment, but also a solution-rich environment. Unfortunately, most solutions also create additional problems.

[Laughter.]

Congressman Bartlett is next.

And we recognize the presence of our Chairman, Mr. Walker. We'll give you an opportunity for questions in just a moment.

Congressman Bartlett.

Mr. BARTLETT. Thank you very much.

Mr. Chapman, you said and you have it in italics in your printed testimony, so apparently you meant it, that PNGV is not corporate welfare. It's quite obvious I think that any manufacturer that produced an automobile that was as big as today's automobiles, performed as well as today's automobiles, was as safe as today's automobiles and got three times the mileage ought to have an absolutely enormous market.

The question is why wouldn't an auto manufacturer pursue this goal without the involvement of government since there obviously would be such an enormous economic incentive to do so? And if indeed they cannot do this without the help of government, could not we be more helpful if we simply relaxed some of the regulations that bedevil our auto industry and if we taxed them less so that they had more money? Help us, please, in defending the federal contribution to this development program.

Mr. CHAPMAN. If I may, I'll split that in two parts and ask my colleague, Mr. Johns, to address the second half.

But with regard to the question of what we're about here in working with the industry, I think there is no disagreement that there are technologies that are resident in the government laboratories or have been supported by the government that are well in advance of anything that the auto industry has put into practice, and these vary from such things as the composite materials that are in the wing structures of B-2 bombers or 117 aircraft or flywheels that are used by NASA to stabilize space platforms or other things that are primarily oriented towards weaponry or missions of various agencies in the way of whatever they're charted by or the Congress has directed them to do.

It is that sort of technology which by its nature is, first of all, very long range, which the translation of it from a particular orientation with regard to weaponry or whatever to automobile application takes quite a bit of research and time to nurture and develop.

We talked earlier about the business climate in which these companies are operating, and again you can ask the auto people what their standard payback time is, but in my days in the industry it was nothing more than about two years. So a 10-year program in the auto industry today is not something you stand up in front of the Chairman of the Board and get rousing support for.

So for all those reasons, the role of the government, the particular dedicated resources that we have and the kind of technology that we're dealing with, as far as we're concerned it's a very good match with the strengths of the technology community and the government with the auto industry.

And I'll turn the other part of the question over to my colleague.

Mr. JOHNS. We, of course, have the cleanest automobiles in the world today, and that's a result of regulation and not inherent good will. I mean, the automobile industry has a responsibility to their stockholders, and they are valued every morning at the stock exchange based on their short-term return on investment, and they are in a very competitive world.

It is hard for them to take capital investments that are achieving R&D goals, which the company does not have to meet, especially when their market is demanding in a sense just the opposite. They are demanding more muscle, they are demanding four-wheel drives, the big square automobiles today not noted for their elegant drag coefficients, and as long as the marketplace dominates, the auto industry has to respond to that.

In order for their R&D dollars to compete, part of our investment, which is a social investment to get clean air because our stockholders expect government to set some standards in those regards, this joint investment makes the R&D investment attractive to the companies.

As you say, if they had such a car it would be a great success, but it requires years of continuity and they would have to build up a capacity that approximates some of the federal R&D enterprise in this country that was for a Stealth aircraft and space activities and so on. If we aren't capitalizing on it for our economic prosperity, we're making a grave mistake.

It also is important to recognize it's a two-way street. If you take a plastic metal forming, which NASA has been at the forefront of for spacecraft activity, they showed a few things to the auto industry, but the auto industry showed a few things to NASA, too, and showed NASA, for example, how to accomplish some of these things in a third to a fifth of the time, even though NASA could show to them an element at the cutting edge.

So our federal enterprise, to accomplish the missions that it has been charged with by this Congress and the Congresses that preceded it, are indeed technologies that can make a difference, and if we don't create the catalytic and the impedance match between this capacity and our industry, we're losing a great opportunity to pursue prosperity and a clean environment.

Mr. BARTLETT. Thank you. Both of you have been very helpful in providing some arguments for explaining why the Federal Government needs to be involved in a program that one might presume would be in the selfish best interests of the industry and why wouldn't they pursue it, or wish to and be able to pursue it on their own.

Mr. Chairman, do I have time for one more question, or should I wait for a second round?

Mr. EHLERS. If it's a brief one. Your time has expired, but if it's a brief question with a brief answer.

Mr. BARTLETT. Both Mr. Gross and Mr. Johns pursued a common theme in a part of their presentation. Our incentives for pursuing this program involve not only our interest in the environment, and obviously a car that burns less fuel will pollute less, not only our interest in the economy, and both of you very correctly pointed out that today we use a fourth of all the world's oil, and we have in this country found less oil and pumped less oil every year I think since the '70s, and that's simply because there is less oil here to find than pump, and the third reason for doing this is one that you gentlemen made plain, that I think a majority of our people in the Congress do not understand and the majority of the people in the nation do not understand, and my question is how do we apprise them of the fact that oil reserves are not forever and that they are, using your terminology a finite resource?

We do not know how finite they are, and what you point out is that the developing nations, when they industrialize and when they demand the same transportation amenities that we have, that our 25 percent of the world's oil use is going to shrink to a much smaller percentage of that, but the overall use of oil in the world is going to go up enormously.

Considering all of these things, what are our finite oil reserves, and how big an incentive should this be to pursue programs like this?

Mr. EHLERS. I would ask that the answer be briefer than the question.

[Laughter.]

Mr. JOHNS. Just a quick cut at this. Seventy-five percent of our oil resources in this country in history have come from 25 percent of the reservoirs because giants and supergiants are really the fields that are the ones that supply a nation. We haven't discovered a supergiant field since 1968, and we have been looking hard in between, not so hard in the last decade, but looking very hard for petroleum.

This decline is very real that is taking place every year, and it is unlikely to turn around, although there are some promising prospects in very deep water in the Gulf of Mexico that we're pursuing actively. It is not going to solve our problems, and neither is Anwar. So we are going to have to wean ourselves from the fossil era. There are both political limits as well as physical limits of the ability of the world, including the Middle East, to produce oil, and those political limits are just as real as their reservoir limits.

Mr. EHLERS. Thank you. That's a good summary.

Out of courtesy to our Chairman, who has graced us with his presence, Mr. Walker, we're pleased to recognize you.

Chairman WALKER. Well Ms. Jackson Lee indicated that she is in the middle of a markup and wished to make a short statement before we got to me, and I would be happy to accommodate her.

Mr. EHLERS. I would certainly be happy to do that if you don't object. Thank you.

Ms. Jackson Lee.

Ms. JACKSON LEE. I thank Chairman Walker for his indulgence and courtesies, and I thank the Chairman of the Subcommittee.

Let me acknowledge to the gentlemen that my departure is not because of my lack of interest. Albeit, I come from the State of Texas that enthusiastically produces and hopes to produce more oil and gas in both a fiscally responsible and clean and effective manner.

I do think it's important that this Committee have oversight over the PNGV program and in fact that we're engaged in the kind of technology research that this program would generate.

I hope as the hearing proceeds and the results are received by the Subcommittee Chair that we'll have an expanded status report on how well the government has managed the program and what accomplishments the program has been able to secure.

I would ask if the Chairman would accept my opening statement to be submitted unanimously into the record and would offer that I would like to pose questions to the panel by writing.

I would suggest that we can work on these technologies prospectively and create work in the 21st century. I've always said that, that science is the work of the 21st century, and in fact may find the utilization of fuel cells that may result in the cross-pollenization, if you will, to have a product that provides for a new generation vehicle. So we would not preclude one over the other.

Mr. Chairman, again thank you for your indulgence. I apologize for having to be in two places at once. The markup is proceeding as we speak.

Thank you very much, and I yield back. I assume it was the time of the Chairman.

Mr. EHLERS. Without objection, the gentlewoman's opening statement will be entered in the record, and she will submit questions in writing to the panel.

Thank you for your attendance for this time.

We will now turn to the Chairman who has a deep interest in this subject, and not only that, has probably driven vehicles faster than anyone in the room.

Mr. Walker.

Chairman WALKER. Thank you, Mr. Chairman.

In fact, I just had an opportunity the other week when I was in Europe to not drive, but ride in a hydrogen-powered vehicle at 100 miles an hour on the autobahn. So there are, in fact, developments worldwide in some of these areas.

I just in glancing through the materials here am very pleased to see some of the accomplishments and some of the intention to work on fuel cell development as a part of the PNGV program. In my view, what we're doing with this program is doing mission-oriented research where we have a multiplicity of problems, all of which impact on the major form of transportation that we have in our society, and that mission-oriented research that is being done here I think can produce some very, very useful results for the nation and for the world.

I am pleased to see that in a lot of what you're doing you are indeed pushing the envelope by looking at technologies that are not at least immediately assumed to be just over the hill in terms of powering automobiles, and I think that that's useful because I think it's very, very important for this program to look beyond simply what the product development is going to be here and to very much push the envelope toward what the vehicle is likely look at 25 years into the next century and begin to move us in that direction.

That's the one thing that I was impressed with in what I saw in Europe, and I would like to have your response to this. In Europe, as they are doing some of this development they are looking at the multi-step process that it takes to get them there. In other words, the people at BMW in developing hydrogen vehicles are looking at the fact that they probably have to do something with regard to natural gas vehicles prior to that so that they develop the infrastructure necessary to take them to where they would have to be in hydrogen.

Could you explain a little bit how you're thinking through this process, and how you're thinking between now and the year 2025 as we look at this program, and how we are thinking about the infrastructure necessary to support the new generation vehicle if it moves beyond the fossil fuel economy?

Mr. CHAPMAN. Well, first of all, sir I would comment that I was at BMW last year, as well as Volkswagen and several other research firms in Europe, and was quite impressed with their European methodical approach to things, tracing all the way back to ore in the ground or gas coming out of some place or other and the loss associated therewith and the efficiencies in the process.

Their approach to their "Car of the Future" is very much environmentally-oriented in a broad sense. The approach that we're taking is not disregarding the environment by any stretch, but is more operating on the presumption that if we have a more efficient vehicle that these other things therefore fall in place.

Up to now we have really been trying to get a definition of the car of the future in a black box sense in that we've tried to sort out all of the available technologies. We have been running a competition, a technical competition between candidates, so that, for instance, in engine conversion, fuel cells versus turbines versus advanced piston engines, energy storage, batteries versus ultracapacitors versus flywheels and so on.

We're at the stage where before long we will begin to determine which of these are most appropriate for applying to the car of the future and which need additional research and so on, and as we start to make these choices the very questions about the infrastructure will loom very large. Clearly if a different kind of fuel is called for in a certain device, that has an effect on what kind of decision you make to go forward.

We have done a first-cut look at what the breadth of the infrastructure issues might be, and each time we go back we find out that we didn't look broad enough. This was reported to the NRC last summer, and we picked up from there and we're moving on. I would say that the infrastructure issues are something that will continue well into the life of the program. So that as we proceed we will move into specific areas as we find that a given component is going to impact or have impacts on the infrastructure. So it's work in progress I guess is my message.

Chairman WALKER. I do know that in some of the work you've been doing, and in a couple of briefings I've had in times I've been in Detroit on the program, one of the things that you do look at, at the present time, is cost-related factors. In other words, hydrogen, as an example, has the problem that the cost of producing the hydrogen to begin with has to be entered into the long-term costs of the vehicle performance, and/or the amount of energy that is consumed in order to produce has to be a part of the overall mix. I realize that you're doing some of that.

I guess I'm also concerned about how the program is following recent developments. I just read the other day, for example, that they have found an enzyme that exists at the boiling point of water that appears to be an opportunity to produce hydrogen very cheaply and may in fact allow us to produce hydrogen out of old newspaper as an example, and that it seems to me is a development then that could have a huge impact on choosing what the next generation of vehicle might look like in terms of performance.

How are you evaluating those kinds of developments that in this new generation are happening very, very rapidly?

Mr. CHAPMAN. I mentioned earlier that we have 10 technical teams that are jointly staffed by representatives from the government laboratories as well as the car people, and with one exception they're all chaired by the industry representatives. Additionally, there are some six or eight consortia and boards or whatever that support these. So within the materials area or within the fuel cell area or within the flywheel area they're charged, in fact, to be as open and as aware of these sorts of developments.

It's all part of a menu with respect to what is very long term and should be followed and at least be aware of versus what's here and now and available if we had to move out to start talking in terms of a specific car configuration.

One further point that I just thought I would mention is the Daimler fuel cell vehicle, which is out driving around now, has two pressure vessels on top where they carry their hydrogen. I think one thing that we've learned is not to let ourselves get too hung-up on what appear to be today's barriers. There are ways we believe for taking other fuels aboard and translating that into hydrogen on the vehicle so that we don't have these massive substantial packages that are required. So again, as we proceed in research if we see barriers we recognize those as such.

I think one of the reports that was given you was a gray covered report called Inventions Needed, and within there we list all these areas where we don't have an answer, but that's what we're all about.

Chairman WALKER. The tankage for the cryogenic hydrogen that BMW was using was very compact and in fact fit easily into the truck and left trunk space besides. So they in fact have dealt with that to some extent by using cryogenic rather than gaseous hydrogen for their vehicle.

Mr. CHAPMAN. There are all these options, yes, sir.

Chairman WALKER. Mr. Gross.

Mr. GROSS. Mr. Chairman, I would just like to mention that I think early in the PNGV's life there was a common misperception that we were working toward a very high fuel economy, but it was going to be gasoline fuel. A number of times this was stated to me as why do you do that, and I said we're not doing that, and I think we're working to break down that perception that has been around.

Within our own organization in the Transportation Technologies Office in DOE we have recently reorganized to form an Office of Advanced Automotive Technologies which includes both the fuel efficiency propulsion system programs, energy storage programs and alternative fuels responsibilities. I think we are very much keying on the importance of meshing the work in propulsion systems with the fuels infrastructure issues and understand we must think through very carefully a fuels strategy.

I would also mention in this regard that I think it's awfully important to recognize the linkage between our program in PNGV and the program in the Office of Utility Technologies that is funded out of Energy and Water, which is under some significant budget pressure, but which supports a lot of the infrastructure work related to hydrogen in particular in the Hydrogen Office there.

We are doing work along with them on hydrogen storage, they on off-vehicle storage and we on on-vehicle, but we have a lot of common technology points of interaction, and I want to put in a plug, I guess, that we look carefully at their budget as we look at this hydrogen infrastructure issue.

Chairman WALKER. Well I'm trying very hard to hold the budget level at the Hydrogen Office as a part of the appropriations process. I must say though it would be helpful if the Administration would come through with numbers higher as well. I mean the Administration cut the number 50 percent below what it got this year in their budget submission. So it's awfully hard to hold it at this year's level with the Administration's request on hydrogen. So I mean both of us are going to have to work very hard in that regard.

One last comment, if I could, Mr. Chairman, and that is it seems to me that one of the things that we all have to realize in this, particularly those of us who are legislators and have a role to play in this program, is that sometimes just because we think of it doesn't mean it necessarily can be done, and I think of some of what is going on in the flywheel technology.

I know Chrysler, in trying to build their Patriot race car, found that that is a very difficult technology to manage. It has real promise, but being able to build flywheels that have durability and can in fact operate at the kinds of speeds that they do is a huge technical challenge that may be at the heart of a number of the different systems that you discuss here. So it's going to be very important for us to realize that some of these do represent significant technical challenges to get from here to there.

Thank you, Mr. Chairman.

Mr. EHLERS. Thank you, Mr. Chairman. We appreciate your attendance here.

I would comment as a physicist that I think the last place I would put a flywheel would be on a racing car because of the gyroscopic effect. If you have a light car and a heavy flywheel every time you turn a corner you're likely to——

Chairman WALKER. You ought to take a look at what they were looking at doing with the Patriot race car. It was a fascinating concept, and it really did have real promise, but the problem is they weren't able to keep the flywheel together for sustained periods of time, and they were hoping to run it at the 24-hour race at Le Mans. So it does mean you've got to keep it together for that period of time.

Mr. EHLERS. Well thank you, and I'm intrigued by your comment that there appears to be a process for extracting hydrogen from used newspaper. If that comes true, we may find the secondary use is far better than the primary use.

[Laughter.]

Unless there are pressing questions for the first panel, we are seven minutes behind schedule in moving to the second one. I take it there are no pressing questions.

We do notice the arrival of Congressman Salmon. We appreciate your attendance.

We thank the panel very much. It has been very useful and informative, and we appreciate your coming here and offering testimony.

We will now ask the second panel to come forward.

Thank you very much.

The second panel will consist of Mr. Robert F. Mull, the PNGV Director at Ford Motor Company, accompanied by his counterparts at the other members of the Big Three, Mr. Peter Rosenfeld from Chrysler and Dr. Ronald York from General Motors Corporation.

In addition, we have Mr. Trever Jones, Retired Chairman of the Board of Libby-Owens-Ford Company, and Chairman of the PNGV Standing Committee of the National Research Council, Dr. Robert L. Hirsh, President, Energy Technology Collaborative, Incorporated, and also a member of the PNGV Standing Committee of the NRC, and finally Professor Daniel Sperling, Director of the Institute of Transportation Studies at the University of California at Davis.

We turn first to Mr. Robert F. Mull.

As you may recall, this was originally two panels. I was very concerned about that because, in my experience, the third panel does not get treated fairly. Everyone has left by then. So I combined the two into one. It does make it a crowded table, but at least you all will have an opportunity to offer your testimony before either the audience or the podium is empty.

So we now turn to Mr. Mull for your comments, and we will allow Mr. Rosenfeld and Dr. York also to make some comments.

STATEMENT OF ROBERT F. MULL, PNGV DIRECTOR, FORD MOTOR COMPANY, ACCOMPANIED BY PETER M. ROSENFELD, PNGV DIRECTOR, CHRYSLER CORPORATION; AND DR. RONALD E. YORK, PNGV DIRECTOR, GENERAL MOTORS CORPORATION

Mr. MULL. Mr. Chairman and Members of the Subcommittee, I appreciate the opportunity to speak to you today about the Partnership for a New Generation of Vehicles, otherwise known of course as the PNGV program.

I'm the Ford Director of the program. On my right is Mr. Peter Rosenfeld, who is my counterpart at Chrysler, and on my left is Dr. Ron York of General Motors.

You've heard from previous speakers about the objectives of the PNGV program, and in particular the ambitious research goals of developing commercially viable breakthrough technologies that would deliver up to three times the fuel efficiency of today's mid-sized cars.

We have defined our baseline vehicle as a mid-sized family sedan as exemplified by the Chrysler Concorde, the Ford Taurus and the Chevrolet Lumina. Our objective is to achieve these breakthroughs while maintaining what is most important to consumers. The consumer mandate includes maintaining affordability, quality, driving range, performance, interior luggage capacity as well meeting safety expectations.

Our goal is framed in these terms so that the resulting vehicles will be appealing to consumers. Market acceptance is necessary to have the impact that we all desire to enhance our nation's energy security and environmental quality.

Today I'm going to give you an overview of how we developed this program, including our management approach, and how well our relationship with the government is working.

To define a technical strategy, the industry began by going back to the very basics of the energy equation of moving people in vehicles. The energy model, shown on the board to the left and in Attachment 3 to the written statement, is for a mid-sized family sedan.

Using this model, ambitious end-point objectives that were judged to be within the laws of physics were established for each energy supply and demand factor shown. Objectives also were set for vehicle mass reduction which, while not shown, affects all supply and demand factors. Approximate mid-point objectives then were set as guide posts to measure whether sufficient progress was being made during the course of the research program. This technical strategy has provided us with a data-driven management process.

While all energy supply and demand factors must improve, the two most critical are for the energy conversion device, or the power plant, and vehicle weight. For the energy conversion device, our objective is at least a 40 percent thermal efficiency. This target is a significant improvement over the approximate 25 percent efficiency of today's spark-ignited internal combustion engine. For vehicle weight we have targeted up to a 40 percent reduction mass of the total vehicle. Every other aspect of the vehicle must make similar improvements, and all of these are enormous technical challenges.

Led by industry in consultation with key government and university scientists, the primary initial competitive technologies for energy conversion devices, energy storage devices and mass production alternatives were agreed on by the third quarter of 1994. These competing technologies are described in our written testimony, in Attachment 4 and are reflected on the schematic of the technical organization structure for the program.

As shown, we have three energy conversion teams made up of a gas turbine team, a fuel cell team and a compression ignition direct injection team, or CIDI team. We have a mechanical energy storage team that covers flywheel and hydraulic pneumatic energy storage and a battery ultracapacitor team that covers electrochemical energy storage alternatives. The electrical and electronics team covers the range of power electronics and motor alternatives.

We have four cross-cut teams as we call them. Because maintaining customer affordability is a critical goal, manufacturing research has been included from the start of the program. The manufacturing team develops priority generic research as well as addresses manufacturing issues for the other enabling technologies. The material and structures team likewise works on research for the ambitious mass reduction goals as well as addressing the material issues of other technologies. The systems analysis team is providing tools to evaluate tradeoffs relative to integrating the enabling technologies into systems. The vehicle engineering team provides direction to all other teams as importantly eventually all components must work in a real car.

Each team includes technical representatives from the auto companies and the government. Many of the members are scientists from the federal lab system. Our teams were in place by the first quarter of 1995.

We began by having the teams define the technical challenges. Once the challenges were defined, the task of establishing research began. As it turned out, considerable efforts, both in the public and private sector, already were underway for the many technologies.

The program management challenge has been to align these existing initiatives thereby achieving focus and discipline. We believe considerable progress has been made in alignment of research, but while we believe that considerable process has been made in aligning research, we recognize that more research had to be established to fill gaps in the program.

Some of these gaps have been addressed by a combination of collaborative and proprietary programs initiated by industry as well as new government programs primarily within the Department of Energy's Office of Transportation Technologies. While progress is being made, significant gaps in meeting the enormous technical challenges remain.

As for our working relationship with the government, we've had mixed experiences. One the one hand, we have been very pleased with the enthusiastic support for many dedicated technical personnel throughout the federal lab system. Much of our collaborative research is aligned with federal agency and lab missions, and we believe that exposure of lab personnel to our industry enhances the labs' capabilities to accomplish their core missions.

One example of a mutually beneficial technology is flame spraying of hardened coatings that are used both for engine bores and neutron generators. Another example is control of distortion during heat treatment that is used to manufacture transmissions and weapons components.

We believe that there are considerable additional opportunities for better alignment of government research to address common technical challenges to the benefit of both industry and government, and our government managers are helping us to realize these additional opportunities.

On the other hand, the complexities of dealing with the Federal Government are a continuing challenge. While the relationship is not perfect, we are working hard and we are continuously improving, and we believe overall the relationship is working. We feel that we have helped the government streamline its administrative processes and believe that as a result of the program, cooperation among the labs is improving.

Another significant aspect of this government/industry partnership is its unprecedented convening power. As a result, we have benefitted from strong participation of the huge network of talent that resides in our nation's supply base, small businesses, the university system and individual inventors with the involvement of over 400 organizations representing many States. This effort is reflected on the map before you. The result we believe is a true national effort using strategic alignment to produce considerable leveraging opportunities for all parties.

In conclusion, we are enthusiastic about this program as an example of what the government/industry partnership can accomplish. Despite enormous technical and administrative challenges, progress is being made, and we desire strongly that a consistent long-term level of government support be established.

We hope our testimony has given the Subcommittee a better understanding of the program and we look forward to answering your questions. Thank you.

Mr. EHLERS. Thank you, Mr. Mull.

[The prepared statement from Chrysler, Ford and General Motors follows:]

"Partnership for a New Generation of Vehicles: Assessment of Program Goals, Activities, and Priorities"

House Subcommittee on Energy and Environment
of the Committee on Science
Chairman, the Honorable Dana Rohrabacher

July 30, 1996

Written Comments from Chrysler Corporation,
Ford Motor Company, and General Motors Corporation

Chrysler, Ford, and General Motors, which together comprise the United States Council for Automotive Research (USCAR), appreciate the opportunity to comment on the status of the important work being done under the Partnership for a New Generation of Vehicles Program. Through this initiative, USCAR and government researchers are coordinating cooperative, pre-competitive scientific research over a broad cross section of technologies.

The goal of the partnership is to develop breakthrough technologies that will improve fuel efficiency by up to three times that of today's vehicles; industry has also agreed to integrate technologies in conventional vehicles as they become commercially viable. Because affordability is a key objective, manufacturing productivity is also a priority.

Key Elements of the Program

Strategic Alignment of Research

A key element of our program model is the opportunity to leverage resources by working cooperatively on pre-competitive research challenges. The program strategically aligns the goals of the three industry partners, including suppliers, with those federal agencies and labs that are engaged in similar or complementary research programs. This process model produces a major leveraging opportunity for each participant by coordinating many previously separate projects into a coherent, focused program.

The majority of the funding for PNGV represents a continuation of research efforts for pre-existing national priorities, many that pre-date the launch of the program. Much of the federal funding is directed to federal labs and government agencies. Of the government funds flowing to the USCAR partners, most is re-directed to suppliers including small, entrepreneurial firms that are leaders in the critical high risk technologies of the program. We wish to acknowledge that the supplier community has contributed significant technical resources in support of program objectives. We believe this model will be successful in improving efficiency of both government research activities and those of industry, while allowing each to pursue independent but complementary research goals.

Research Focus

Research under the three goals of PNGV necessarily spans the range of exploratory research from the most fundamental scientific questions to engineering development of new, practical devices. Likewise, funding sources for this work also range widely, and appropriately, from mainly government funding for long-range work, to entirely industry funding for shorter-term projects. The following examples illustrate the nature of research activities and their value to the U.S. research establishment and to American industry.

Materials science and surface physics is a cornerstone of much of the work in this program. Representative examples include characterizing the behaviors of new composite materials for structural use and investigating new diamond and sprayed-metal coatings for wear surfaces. Most goods manufactured in this country could benefit from breakthroughs in these areas.

Fundamental electro-chemistry underlying batteries and ultra-capacitors is being investigated in order to select the chemical systems and materials most amenable to scale-up and development into practical energy-storage devices for vehicles. Eventual applications of this work could extend to the computer, electronics and power industries, and to support a number of national defense applications.

Work to understand the intrinsic properties of membranes and electrodes for proton exchange membrane (PEM) fuel cells is leading to order-of-magnitude reductions in cost for these components. Ultimate use of these devices in both mobile and stationary applications could sharply reduce both civilian and military fuel demands and emissions.

Attachment I provides other examples of research progress.

The continual cross-fertilization of these and other topics under PNGV among researchers in universities, federal laboratories, and industry provides a rich problem set for investigation and stimulates innovation among a scientific and engineering workforce with unique skills.

The Critical Role of Government

A key factor contributing to progress under this initiative is the successful implementation of an ambitious and unique public/private sector partnership. Government involvement is crucial to support development of breakthrough technologies needed to significantly improve the next generation of transportation vehicles and the coincident manufacturing research to ensure manufacturability at world-class levels of quality, cost, and durability. Although the market does not presently demand high fuel efficiency vehicles, we believe that PNGV research goals are clearly in the public's broad interest and should be developed as part of a mutual industry-government commitment to environmental stewardship.

Government historically has demonstrated responsibility and commitment to undertake long-term, high-risk, basic research in support of national priorities. In this case, the auto manufacturers have a complementary role, but our R&D is more focused on meeting the needs of our customers. The two sectors working together will most effectively and efficiently make the necessary technological advances. As noted before, the strategic alignment of the goals of manufacturers and suppliers with those of federal agencies and labs that are engaged in similar or complementary research efforts, should result in significant efficiencies through coordination of many previously separate or independent projects into a cohesive program.

Industry/Government Technical Cooperation

The introduction of the expertise and unique facilities resident in the federal lab system is one of the key structural elements of the PNGV program. Industry and the labs are working jointly on research solutions to common technical challenges. Industry provides market-sensitive capabilities in high-volume, low-cost product design and manufacturing know-how.

A number of valuable relationships between industry and government scientists have developed over the years, some pre-dating the formation of the PNGV program. Examples of meaningful research initiatives that have been established include our collaboration in advanced batteries for electric and hybrid electric vehicles, weight-reduction efforts through the introduction of substitute structural composite and aluminum materials, and the development of low-cost, package-efficient fuel cells for mobile applications. Other work, with the Department of the Army, includes establishment of research initiatives on technologies aimed at highly efficient compression-ignition, direct-injected (CIDI) engines.

To facilitate government/industry cooperation, there have been numerous reciprocal visits between industry R&D personnel and federal laboratories' scientists. We also utilize workshops on specialized technical topics to bring together researchers from the federal laboratories, universities, USCAR and existing and potential new suppliers. These workshops and visits have fostered open communication about research challenges and alternative approaches. Information about PNGV, including needs and opportunities, has been broadly disseminated at public meetings, with printed reports and via the Internet.

We have been able to align resources and missions to produce strong, effective working relationships between industry and several government agencies and laboratories. However, there are opportunities for strategic leveraging that are being missed and some existing relationships that are at risk. A common misconception is that PNGV would divert resources away from agency missions. We have been working consistently to correct these misunderstandings and to identify technical program alignments that produce mutual benefits. In addition, important existing programs are in danger of being cut off prematurely because of both fiscal and policy constraints.

Industry/Government/Supplier Pull

The program is far more than a Washington - Detroit partnership. Because of the unprecedented convening power of this partnership and the potential broad application of the technology throughout the economy, we have benefited from strong participation of the huge network of talent that resides in our nation's supply base, small businesses, the university system, and individual inventors with the involvement of over 400 organizations, representing virtually every state in the nation (reference Attachment II). This expanded participation also provides an alternative pathway for the technology developed under PNGV to flow to other important product sectors, including Defense. The result is a true national effort, using strategic alignment to produce considerable leveraging opportunities for all parties.

Other Benefits

Voice of the Consumer

A critical element of this collaborative model is to use the voice of the consumer to establish objectives and make critical business decisions. The voice of the consumer comes to the PNGV process through industry, which is leading the technical program and will make decisions on which technologies to integrate and validate in production prototypes by the middle of the next decade that will offer the same functionality and safety, while maintaining the affordability, of today's conventionally designed vehicles.

Budget Reduction

We applaud Congressional efforts to improve the efficiency of federal research investments and recognize that deficit elimination and other fiscal priorities may necessitate some restructuring of programs. Regardless of the level of federal funding Congress authorizes, we believe that direct interaction between the labs and the private sector will result in the most efficient utilization of funds. We are convinced that direct interaction with private sector research activities on joint projects should result in the quickest and most efficient program implementation. We believe that cooperation and interaction among government agencies and labs is improving. Our hope is that this will result in better coordination of the federal R & D portfolio.

Alternative to the Regulatory Process

PNGV is a research program and is not tied to the regulatory process. It does, however, represent a new paradigm for government and industry to jointly tackle problems of common interest through cooperation and mutual trust. This program represents an important precedent for a "new way of doing business" between industry and government -- a quicker, more efficient, and more effective way of reaching societal goals than the adversarial and costly regulatory mechanisms relied on traditionally.

Program Status Update

We have established a sensible program to address the objectives of the PNGV program.

The first thing the industry did was to go back to the very basics of the energy equation in moving people in vehicles. This model, shown on Attachment III, is a 1994 mid-size family sedan equivalent to the Concorde, Taurus or Lumina. Using this model, ambitious end-point objectives, that were judged to be within the laws of physics, were established for each energy supply and demand factor shown. Then, approximate mid-point objectives were set to provide guideposts to measure whether sufficient progress was being made during the course of the research program. This has provided the framework for a data-driven technology management process.

While all energy supply and demand factors must improve, the two most critical areas of improvement are for the energy conversion device, or power plant, and vehicle weight. For the power plant, our objective is at least a 40% thermal efficiency compared with today's spark-ignited internal combustion engine efficiency of about 25%. For vehicle weight, we have targeted up to a 40% reduction in mass of the total vehicle. Every aspect of the vehicle must make similar improvements. These are enormous technical challenges.

Led by industry, in consultation with key government and university technical personnel, the primary initial competitive technologies for energy conversion devices, energy storage devices and mass reduction alternatives were agreed on in the third quarter of 1994. These are described on Attachment I and are reflected on the schematic of the technical organization structure for the program on Attachment IV. Each team is made up of the technical representatives from the USCAR participants and from the government; many of the members are from the federal lab system. These teams were in place by the first quarter of 1995.

A key task for the teams was to define the technical challenges that must be overcome. Importantly, because maintaining customer affordability is a critical goal, manufacturing research has been included from the start. Once the challenges were defined, with metrics used to the extent possible, research efforts then had to be directed toward addressing the challenges. As it turned out, considerable effort both in the public and private sectors was already underway for many of the technologies. The program management challenge has been to align these existing initiatives, thereby achieving focus and discipline. We believe considerable progress has been made in this alignment and in identifying remaining gaps in the program.

While many of the technical challenges were at least partially being addressed by re-aligning existing research, significantly more dedicated research had to be established. The primary source of funding for this work is the Department of Energy (DOE) Office of Transportation Technologies (OTT). A common misconception is that these funds flow directly to the OEMs, when in fact the funds primarily go to suppliers and labs working on the technical challenges for the high risk technologies of the program. Critical vehicle system research work also is funded by OTT in the form of the Hybrid Propulsion System (HPS) programs.

To evaluate the technical status, the teams have consensed on whether progress is in the Green, Yellow, or Red categories for each technical challenge. These codes reflect whether the research is proceeding on schedule, needs a greater dedication of resources, or is seriously jeopardized. At this time, considerable Yellow and Red codes exist largely because of the enormous technical challenges relative to the resources provided.

Attachment I describes the principal areas of technical development and highlights some of the results achieved to date. The list is not exhaustive and does not describe proprietary efforts in any great detail.

Independent Peer Review

In April, the National Research Council (NRC) issued its second annual Peer Review report that examined the program's overall technical and management strategies, and the state of progress after two years. The NRC panel noted that "Significant benefits can be anticipated from the program," but cautioned that "The technical challenges are daunting, and,...inventions and breakthroughs are needed and are difficult to anticipate". Furthermore, the report states that at this early stage of the program, it would be premature to categorize the technologies under development into winners and losers.

The program has responded to the NRC recommendations and benefited. A stronger effort on systems analysis has been implemented, and a further delineation of technical selection criteria has been developed for review with the panel this fall. Furthermore, the program has benefited already from the identification of a direct contact in the Office of Management and Budget to assist in the challenges of coordinating this inter-agency project.

Overall, the NRC concurred in our selection of promising technologies and the specific technical objectives that have been defined. We agree with the panel that the alignment of resources to address the technical challenges has not been fully optimized.

CONCLUSION

Chrysler, Ford, and General Motors believe that continuation of the program is in the best interests of consumers, our industry, the government and the nation. We believe that this important initiative represents the best approach to achieving many national priorities -- including enhanced environmental protection, reduced energy consumption, and improved national competitiveness.

We believe in the merits of research being conducted under collaborative programs, and are prepared to maintain a meaningful core level of effort and resource expenditure on such programs regardless of short-term fluctuations in the level of federal support necessitated by the effort to balance the federal budget. Significant additional cuts, however, in the level of federal funding undoubtedly will delay achievement of many research goals and perhaps require a rethinking of the scope of the program. We would be pleased to work with Congressional and government staffs and others, as needed, in an effort to integrate both fiscal and research priorities and to ensure the continued success of this important initiative.

Thank you for the opportunity to comment on the Partnership for a New Generation of Vehicles program.

July 30, 1996

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Attachment I

EXAMPLES OF PNGV TECHNICAL ACCOMPLISHMENTS

Energy Conversion

Fuel cell developers continued their rapid advance in reducing the size of the cell stack required to produce sufficient power for a vehicle. In the last year, size was reduced by a factor of two, with further gains projected. Also, several developments have reduced the projected cost of fuel cells. These include a major reduction in the catalyst loading required, scale-up of the catalyst application process to permit high volume production, and new materials and processes for manufacturing bi-polar plates at substantially lower cost. The major technical challenge for fuel cells is how to manage the fuel in the vehicle. On-board reformers and processors, for converting liquid fuels (e.g. methanol and gasoline) to hydrogen, have been demonstrated, but require significant additional development to improve cost, weight, and efficiency. On-board storage of hydrogen is also being studied aggressively. The key challenges are the low energy density of known hydrogen storage technologies and the infrastructure issues related to manufacture and distribution of the fuel. Programs are in place to address these challenges.

The **Gas Turbine** is an attractive powerplant for a hybrid vehicle because of its inherently clean combustion system, excellent noise and vibration characteristics, high power density and simplicity (low parts count). Progress is being made on the key challenge of affordable structural ceramics. Ceramic vanes and blades necessary for high efficiency turbine operation have successfully completed 1000 hour rig testing. Gelcasting, a lower cost net-shape manufacturing process for the ceramic rotors, has been demonstrated. Progress was made in developing and demonstrating a low cost extrusion process for manufacturing the ceramic regenerator core to recover turbine exhaust heat.

Compression-Ignition Direct-Injection (CIDI) engines offer superior fuel economy, but require significant reductions in the emission of particulates and nitrogen oxide if this technology is to be used in the U.S. beyond 2000. The key enabling technology is a catalytic converter which must operate under lean-burn (high oxygen) conditions to meet future reduced levels of nitrogen oxide and particulate emissions. A large number of catalyst formulations have been evaluated under lean-burn conditions and formulations with promising results have been selected. Full size catalytic converters are being prepared for on-vehicle evaluation. In addition, using a CIDI engine fitted with a quartz window and advanced laser diagnostics, researchers are able to see how the fuel mixes with air in the combustion chamber, how it auto-ignites and burns, and how soot and nitrous oxides are formed. These detailed observations have given researchers a better understanding of processes crucial to reducing exhaust emissions. Research is also continuing on alternative fuel formulations that offer potential for reducing emissions.

Energy Storage and Electronics

Lithium Ion batteries are one of the prime candidates to meet the high power, high energy-density and high cycle-life required for a hybrid vehicle. They have potentially four times the energy-density of lead acid batteries and two to three times that of nickel cadmium and nickel metal hydride batteries. Electrode materials have been developed for lithium ion batteries that do not use metallic lithium, thus enhancing safety and cycle life of the battery. These materials have been found to be stable over the wide operating temperature range needed.

Ultracapacitors are energy storage devices with very high power density, for use in conjunction with batteries or on their own. Carbon-based and advanced multi-layer materials have been developed with potential to substantially improve ultracapacitor cost and performance. These materials have the potential for low cost manufacturing, improved energy-density, low self-discharge, and high round-trip efficiency.

Power Electronics for both hybrid electric and pure electric vehicles manage voltages ranging from 12 to 300 volts, control currents, and accomplish AC and DC power conversions. Cost and efficiency of the power electronics are major challenges for these vehicles. Because these are problems common to both civilian and military power systems, it is a fertile area for collaboration. A U.S. Navy program called Power Electronics Building Blocks (PEBB), is expected to yield significant engineering, manufacturing, and cost benefits to the automotive industry as well as throughout the defense establishment for ships, airplanes, and ground vehicles.

Mass Reduction

An **aluminum body** structure can provide a 50% to 55% reduction in mass, but the cost of aluminum is a major barrier to implementation. An aggressive program evaluating alternative forming and joining methods and new alloys is in place to lower cost. Continuous slab casting, which has the potential to lower substantially the cost of aluminum sheet, has been used to manufacture automotive-grade sheet material for fabrication trials. Also, in the past year the number of medium and high volume automotive aluminum body panel applications has increased substantially, adding to confidence in the forming, joining and painting of aluminum.

A conceptual design for a **steel space-frame** vehicle structure has been completed. Although significant challenges remain, the concept has the potential for 50 percent weight reduction while reducing both manufacturing and tooling costs compared with a conventional unitized steel body structure.

The design phase for an **Ultra Light Steel Auto Body** (ULSAB) concept, which uses high-performance steel materials and advanced manufacturing methods, has been completed. The concept, which is in the testing and validation process, potentially saves 25% or more weight than conventional methods, reduces the number of stampings, increases vehicle stiffness and reduces overall cost.

For **polymer composites**, a Structural Reaction Injection Molding (SRIM) process was demonstrated on an automotive underbody crossmember. This process has the potential to support high-volume automotive production. Progress has been made in understanding and predicting crash impact energy management with composites, including finite element analysis tools, and the design and crash testing of composite vehicle front ends.

Manufacturing Technology

Powder paints can reduce emissions from paint operations because the paint is applied in a cloud of dry particles rather than as a wet mist, and overspray can be collected and reused. Under USCAR, the Low Emissions Paint Consortium has undertaken an aggressive program to develop and verify a powder paint clear coat process with the quality and reliability to be used commercially to replace the liquid clear-coat paints on car exteriors.

Diamond-like carbon material has the potential to reduce wear and friction in critical automotive power source components, including: piston rings, cylinders, valve guides and stems, and fuel injectors. The performance of these carbon coatings has been evaluated with promising results, and several potentially cost-effective methods of depositing the coatings have been evaluated.

Vehicle Development

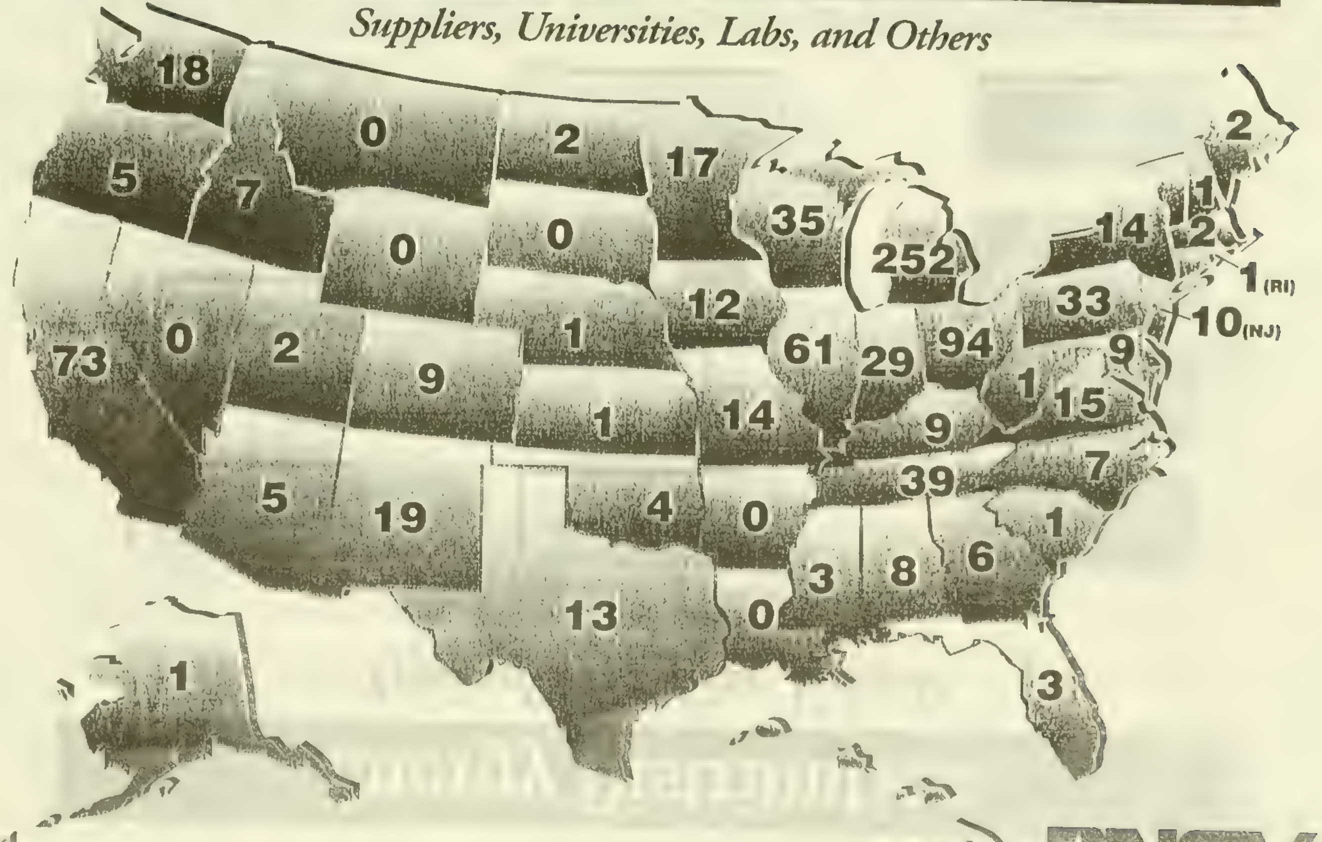
An initial version of a new **vehicle simulation** software tool has been developed and is being benchmarked to verify its accuracy. This tool allows evaluation of performance and fuel economy of different vehicle concepts and configurations. It will also be used for guiding technology targets and performance requirements of key vehicle components.

Reduced rolling resistance **tires** are key to improved fuel efficiency. Advanced computational modeling tools have been developed for the design and manufacture of automobile tires. The new predictive capability facilitates tire design for low rolling resistance while maintaining other key tire performance measures, such as braking, handling and long life.

Attachment II

USCAR/PNGV Liason and Project-Sites*

Suppliers, Universities, Labs, and Others



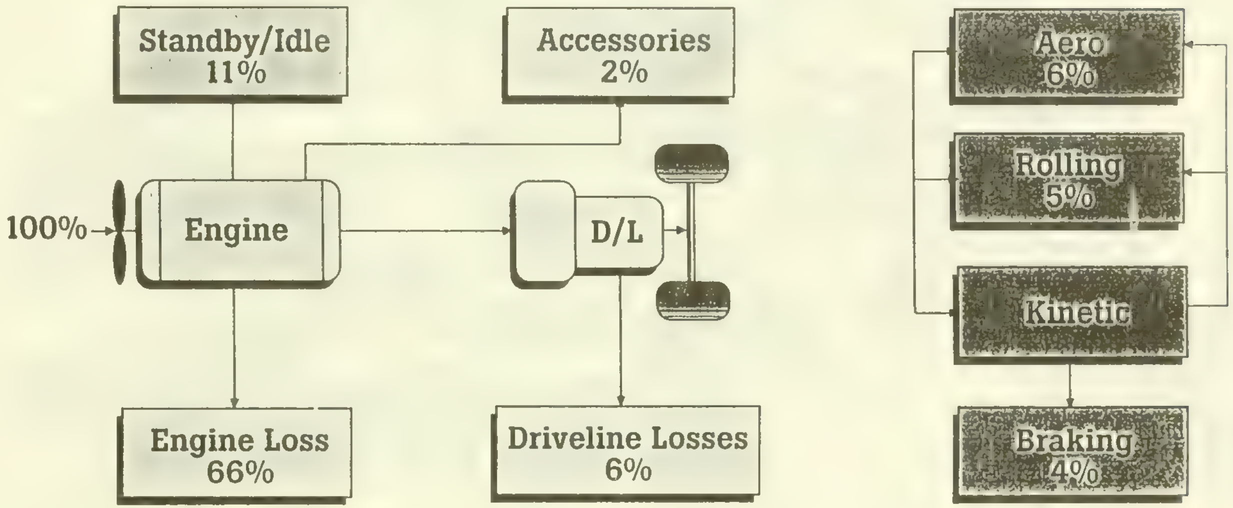
As of June 10, 1996

PNGV
PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

Attachment III

Energy Distribution

Typical Mid-Size Vehicle



100%

Standby/Idle
11%

Engine

Engine Loss
66%

Accessories
2%

D/L

Driveline Losses
6%

Aero
6%

Rolling
5%

Kinetic

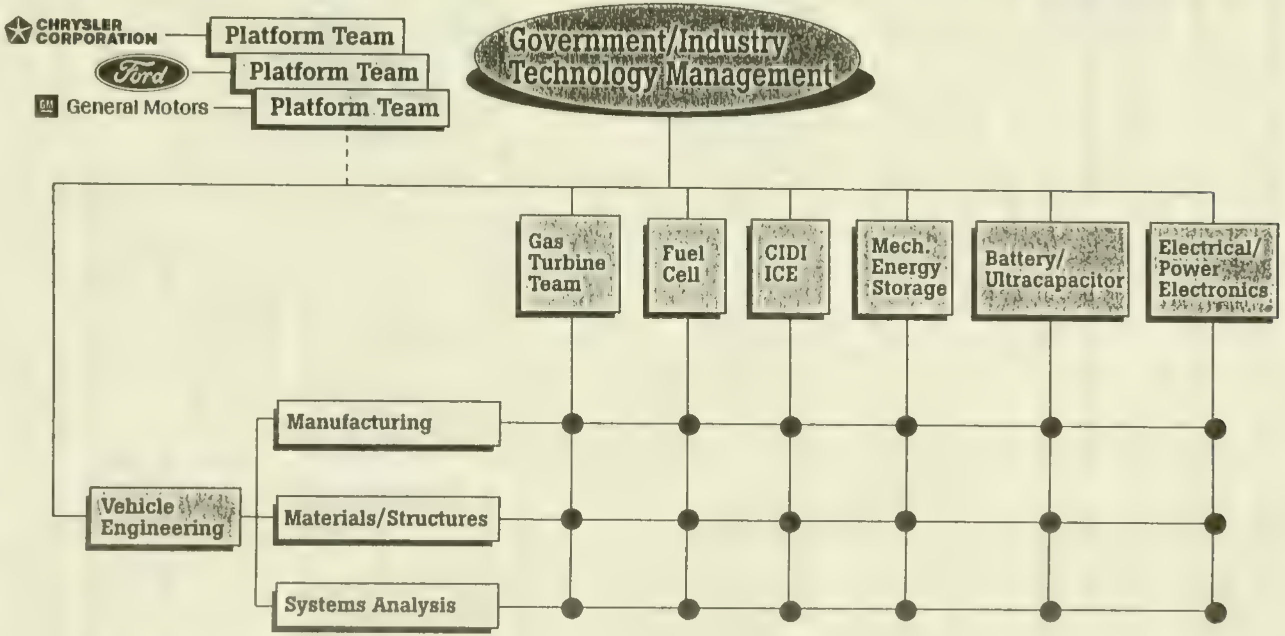
Braking
4%

METRO–Highway Cycle

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

Attachment IV

Technical Organization Structure



CHRYSLER CORPORATION — Platform Team

Ford — Platform Team

General Motors — Platform Team

Government/Industry Technology Management

Gas Turbine Team

Fuel Cell

CIDI ICE

Mech. Energy Storage

Battery/ Ultracapacitor

Electrical/ Power Electronics

Vehicle Engineering

Manufacturing

Materials/Structures

Systems Analysis

PNGV

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

Mr. EHLERS. Mr. Rosenfeld.

Mr. ROSENFELD. No additional comments, other than the testimony represents our collaboration.

Mr. EHLERS. Thank you. I appreciate that.

Dr. York, do you have anything you wish to add?

Dr. YORK. The same. No.

Mr. EHLERS. Mr. Trever Jones, we'll turn to you next.

STATEMENT OF TREVER O. JONES, CHAIRMAN OF THE BOARD (RETIRED), LIBBY-OWENS-FORD COMPANY, AND CHAIRMAN, PNGV STANDING COMMITTEE, NATIONAL RESEARCH COUNCIL

Mr. JONES. Good afternoon. I am Trever Jones, Chairman of the NRC-PNGV Review Committee. With me today on my right is Dr. Robert Hirsch, who will provide comments on the PNGV program management.

Since there was some perhaps misunderstanding on who NRC is, the PNGV partnership in the beginning of the program asked that the National Academy of Sciences review the program on a periodic basis for the organization conduct and the appropriateness of the R&D activities being pursued. The NRC is in fact the operating arm of the National Academy of Sciences.

Specifically, your invitation asked that we testify on the results of our annual reviews of the PNGV program and the program responsiveness to these recommendations.

Let me start at the outset that the PNGV has made significant progress in organizing and conducting an R&D program to develop technologies which have the potential to meet its extremely ambitious performance goals and tight schedules. This progress is even more impressive when recognizing that PNGV is a coalition of private industry and federal laboratories, that the USCAR consortium partners are marketplace competitors, and it is less than three years since the program was initiated. The program participants' widely different cultures are working together with the single purpose of developing highly efficient and cost-effective globally competitive automobiles for the next century.

In the time allocated to me I will comment on a number of topics which I believe will be of interest to your Committee. For completeness I have provided a summary of our Committee's Phase II report for the record of this meeting.

Since the success of the PNGV program relies on some critical technology breakthroughs, I feel it important to advise you of some guidelines adopted by our Committee.

First, we accepted the vehicle performance goals and objectives of the program as a given. I will not repeat them here since you addressed them in your opening comments.

The reason for our Committee's position was that PNGV is a 10-year R&D program which must rely on fundamental technological breakthroughs in order to meet the specified goals. The NRC Committee would have had to conduct in-depth research of its own in order to determine the reasonableness of the PNGV goals and objectives. The Committee felt that it was more appropriate to monitor the progress of the PNGV program through the first three years to the point of technology down select in December 1997, and then assess the state of technology against the PNGV goals.

The Committee was also fully aware that a previous NRC study had been conducted to estimate the practical upper limit of fuel economy achievable with contemporary technology. This study concluded that about half of the PNGV fuel economy goal could be achieved for mid-sized passenger cars. The results of this study supports the need for an aggressive R&D program in order to meet the PNGV objectives.

The second guideline was that in the absence of compelling data, the NRC Committee would not suggest terminating R&D in any of the PNGV-selected research and development areas during the first two reviews of the program. The reason for this was that PNGV to a large extent was a continuation of ongoing R&D programs with extremely ambitious goals, and to suggest dropping any approaches in the first 24 months of a 10-year program would be inappropriate.

We did, however, recommend a more appropriate balance of expenditures between the various candidate technologies based upon progress in R&D and improved estimates of probabilities of success. We also decided that the more appropriate time to firmly examine the potential of each technology was during the technology down select analysis at the end of 1997, which is a major PNGV milestone.

Our Committee also reviewed alternative technologies not being considered by PNGV and concluded that no obvious contenders have been overlooked or omitted.

The third guideline I would like to address concerns Goals 1 and 2 which are directed towards significantly improving our national competitiveness in manufacturing, namely Goal 1, and to implement commercially viable innovations from ongoing PNGV research on current vehicles, namely Goal 2.

Our Committee has devoted limited time to Goals 1 and 2 because neither goal has quantitative objectives. Hence, measurement of progress is difficult. Also, there is significantly less risk associated with Goals 1 and 2 compared with Goal 3.

Notwithstanding, a credible effort has been devoted to Goals 1 and 2 resulting in the early introduction of a number of useful ideas and processes. The PNGV program recently issued a document, which has been referred to here many times, which describes 65 technical accomplishments, of which more than 50 percent can be classified as Goal 1 and 2 achievements. The accomplishments in this document are consistent with our Committee's reviews in these areas.

Turning to systems analysis, the PNGV program is a very broad complex program in terms of vehicle requirements and potential technology candidates. When confronted with extremely ambitious performance goals for very complex systems, it is essential that a total systems analysis approach be used. Such an approach permits development engineers and scientists to evaluate the influence component, subsystem and total vehicle designs on performance of many technology options over a wide spectrum of operating conditions. It is highly desirable to include production cost in these models in order to provide comparative cost information in support of final technology and design option selection.

Our NRC Committee feels that sound systems engineering analysis is fundamental to the success of the PNGV program and mandatory to the economic application of R&D effort and funds. Unfortunately, the initiation of this activity at USCAR was almost a year late in getting started. This was a critical period because of the closeness of the 1997 technology down select milestone. This delay was all the more disconcerting because the amount of funds required was relatively small compared with the total funds being expended on PNGV.

The systems analysis effort is now under contract and our Committee will review its progress in September of this year when we commence the third review of the PNGV program.

This delay raises an important question which in turn exposes a fundamental issue in the PNGV program. The basic question is, did the PNGV program languish during this systems analysis hiatus? The answer is no because each USCAR partner used its own system models to fully support their individual in-house PNGV development programs and in a limited way the overall PNGV program. These in-house systems models are not fully shared between the three USCAR partners because they are deemed to be of competitive significance and, hence, proprietary.

The claim by each of the USCAR partners as to what is and what isn't competitive is critical to the degree of information sharing and consequently the extent of the R&D leverage achievable in the PNGV program. The difference between pre-competitive and competitive information is an extremely difficult line to define.

In general it is my view that competitive technology advantages are short lived because the industry quickly converges to a state of technological parity. My observation is that the USCAR partners are overly sensitive or perhaps too optimistic over the real competitive advantages provided by their individual technologies which they elect to classify as proprietary.

It is clearly not for our Committee to dictate to the USCAR partners what should or should not be shared. Nevertheless, the NRC Committee observes that excessive proprietary classification by the individual USCAR partners in the PNGV context can impede the program's progress, increase the degree of redundancy which results in the reduction of R&D leverage per dollar invested and thus defeats an objective of the PNGV program.

On technology selection and assessment I would like to review with you a summary chart which provides our comments and views in a very broad sense of the potential of the major technologies under consideration by the program.

[Chart shown on screen.]

At the present time it is considered highly likely that PNGV candidate vehicles will need to recapture vehicular kinetic energy during braking in order to meet the 80 mile per gallon fuel economy target. The simplest known technique for this is through electrical regeneration and energy storage. This in turn leads to a basic decision that the drivetrain will be some form of hybrid-electric. The three principal energy converters under consideration, shown in the upper left-hand corner of this chart, are the diesel engine, turbines and fuel cells which would operate in a hybrid-electric mode. The leading energy storage candidate systems are either electrochemical, namely batteries, or electro-mechanical, namely flywheels.

Another major consideration is the tradeoff between vehicle weight reduction and improvement in energy conversion efficiency. Hence, lightweight alternative materials, such as polymer-based composites, aluminum and lightweight high alloy steels are important candidates.

This chart summarizes the various technology candidates being developed, the critical technological barriers, the ability of the technology to meet the cost objectives and the likelihood of meeting PNGV schedules. Two further columns show the overall potential of the individual technologies regardless of the schedule and the basic current program needs in the right-hand column.

In reviewing the energy conversion or powertrain part of the vehicle, the direct injected compression ignition, or diesel engine, is rated as having the highest probability of meeting the PNGV objectives. The critical research challenge is to develop an effective and durable catalyst for controlling emissions of nitrogen oxides. More efforts and funds are needed to meet this challenge within the PNGV time frame.

The fuel cell and turbine are rated equally at this point in time. In the absence of unexpected short-term breakthroughs, neither system is expected to meet vehicle cost or schedule requirements of the program. On a long-term basis, the fuel cell has very attractive performance and emission characteristics. However, it will not be initially competitive until an economical fuel reformer is developed to generate hydrogen on board the vehicle.

In terms of electro-chemical energy storage, most of the same problems exist which prevent the conventional electric vehicle from becoming a viable and economic form of personal transportation in the near future. There are significant R&D programs devoted to battery breakthroughs. However, at the same time the Committee feels that there needs to be more focus and added resources.

The flywheel as an electro-mechanical energy storage device holds promise. However, there are some concerns as to the safety of the device in vehicle crash situations. As with batteries, the Committee feels that there needs to be more focus and added resources on flywheel R&D.

The final major category is materials. The program has set an objective of a vehicle weight reduction of up to 1,400 pounds or 40 percent. It is unlikely that this weight reduction can be achieved with steel, and it's equally unlikely that it will be achieved with polymer composites for reasons of cost. Aluminum is very attractive and production vehicles are currently being built with aluminum bodies today. However, the most probable outcome will be the use of all of these materials in one form or another.

Turning to your second question as to how responsive have the PNGV partners been to the Committee's reports and recommendations. In general, the partners have been responsive and have found many of our Committee's recommendations helpful. As you can expect, this does not mean that they agree with all of our positions or accept all of our recommendations. The nature of the partnership, namely one-half competitively industry, and the other half a broad coalition of a wide array of government entities, requires our Committee to fully understand and appreciate the environment in which the program is being conducted when providing and tailoring these recommendations.

Our Committee's Phase II report contains 20 recommendations for the PNGV program, most of which PNGV had addressed and accepted. Some are considered outside the scope of the program at the present time. For example, the impact of the ultimate vehicle design on the national infrastructure related to vehicles and highway transportation.

The final topic I would like to discuss is foreign technology. Even though PNGV is an American program for the benefit of American taxpayers, it is mandatory that PNGV constantly evaluate global technology developments.

[Chart shown on screen.]

This chart is a crude, and I emphasize a crude first approximation of the relative position of the United States, Europe and Japan in the development of critical PNGV technologies. As can be seen, the United States is not rated first in each of these technologies, and in fact is rated second and third in the critical areas of lightweight materials and compression ignition engines.

The internal combustion and compression ignition engine, Europe is rated first, Japan second and the U.S. third.

In lightweight materials, Europe—first in aluminum, Japan—first in high-strength steel, and the United States—second.

The PNGV has responded to these observations and it is the Committee's understanding that they are devoting more attention to foreign technology assessment and availability.

I would now like to introduce Dr. Robert Hirsch of our NRC PNGV Committee to provide some views on PNGV organization and management, unless you have questions at this time.

Mr. EHLERS. We will delay with questions.

[The prepared statement of Mr. Jones follows:]

[redacted]

Testimony Before the House Science Committee on the Partnership for a New Generation of Vehicles (PNGV)

by

Trevor O. Jones, Chairman
Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles (PNGV)
National Research Council

July 30, 1996

Introduction

Good afternoon. I am Trevor Jones, Chairman of the NRC-PNGV Review Committee. With me today is Committee member, Dr. Robert Hirsch, who will provide comments on the PNGV Program Management.

Specifically, your invitation asked that we testify on the results of our annual reviews of the PNGV Program and the Program's responsiveness to these recommendations.

Let me state at the outset that PNGV has made significant progress in organizing and conducting an R&D program to develop technologies which have the potential to meet its extremely ambitious performance goals and tight schedules. This progress is even more impressive when recognizing that PNGV is a coalition of private industry and federal laboratories, that the USCAR consortium's partners are marketplace competitors, and it is less than three years since the program was initiated. The program participants' widely different cultures are working together with the single purpose of developing a highly efficient and cost effective, globally competitive automobiles for the next century.

In the time allocated to me, I will comment on a number of topics which I believe will be of interest to your committee. For completeness, I have provided a Summary of our Committee's Phase II report for the record of this meeting and a copy of my curriculum vitae.

Guidelines

Since the success of the PNGV program relies on some critical technology breakthroughs, I feel it important to advise you of some guidelines adopted by our NRC Committee.

First, we accepted the vehicle performance goals and objectives of the program as a given. In general, they are the equivalent of an 80mpg midsize car which matches the performance, passenger comfort and size of today's Taurus-Lumina-Concorde automobiles, while meeting government standards for safety and emissions prevailing in 2004. The PNGV vehicle is to cost no more than the equivalent vehicles adjusted for economics to the year of initial production in 2004.

The reason for this position was that PNGV is a ten year R&D program which must rely on fundamental technological breakthroughs in order to meet the specified goals. The NRC Committee would have had to conduct in-depth research of its own in order to determine the reasonableness of the PNGV goals and objectives. The Committee felt that it was more appropriate to monitor the progress of the PNGV program through the first three years to the point of technology down select in December 1997, and then assess the state of technology against the PNGV goals.

The Committee was also fully aware that a previous NRC study[1] had been conducted to estimate the practical upper limit of fuel economy achievable with contemporary technology. This study concluded that about half of the PNGV fuel economy goal could be achieved for mid-sized passenger cars. The results of this study supports the need for an aggressive R&D program in order to meet the PNGV objectives.

The second guideline was that in the absence of compelling data, the NRC Committee would not suggest terminating R&D in any of the PNGV-selected research and development areas during the first two reviews of the program. The reason for this was that PNGV is an R&D program with extremely ambitious goals and to suggest dropping any approaches in the first 24 months of a ten year program would be counterproductive. We did, however, recommend a more appropriate balance of expenditures between the various candidate technologies based upon progress in R&D and improved estimates of probabilities of success. We also decided that the most appropriate time to firmly examine the potential of each technology was during the technology down select analysis at the end of 1997 -- a major PNGV milestone.

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[1] "Automotive Fuel Economy - How Far Should We Go?" National Academy Press, 1992.

Our Committee also reviewed alternate technologies not being considered by PNGV and concluded that no obvious contenders have been overlooked or omitted.

The third guideline I would like to address concerns PNGV's Goals 1 and 2 which are directed towards significantly improving our national competitiveness in manufacturing - namely Goal 1; and to implement commercially viable innovations from ongoing PNGV research on current vehicles - namely Goal 2.

Our NRC Committee has devoted limited time to Goals 1 and 2 because neither goal has quantitative objectives, hence the measurement of progress is difficult. Also, there is significantly less risk associated with Goals 1 and 2 compared to Goal 3.

Notwithstanding, a credible effort has been devoted to Goals 1 and 2 resulting in the early introduction of a number of useful ideas and processes. The PNGV program recently issued a document on Technical Accomplishments, which describes 65 accomplishments, of which more the 50% can be classified as Goal 1 and 2 achievements. The accomplishments in this document are consistent with our Committee's reviews in these areas.

Systems Analysis

The PNGV program is very broad and complex in terms of vehicle requirements and potential technology candidates. When confronted with extremely ambitious performance goals for very complex systems, it is essential that a total systems analysis approach be used. Such an approach permits development engineers and scientists to evaluate the influence of component, subsystem and total vehicle designs on performance of many technology options over a wide spectrum of operating conditions. It is highly desirable to include production cost in systems models in order to provide comparative cost information in support of final technology and design option selection.

Our NRC Committee feels that sound systems engineering and analysis is fundamental to the success of the PNGV and mandatory to the economic application of R&D effort and funds. Unfortunately, the initiation of this activity at USCAR was almost a year late in getting started. This was a critical period because of the closeness to the 1997 Technology down select milestone. This delay was all the more disconcerting because the amount of funds required was relatively small compared with total funds being expended on PNGV.

The systems analysis effort is now under contract and our Committee will review its progress in September of this year when we commence the third review of the PNGV program.

This delay raises an important question which in turn exposes a fundamental issue in the PNGV program. The basic question is did the PNGV program languish during this systems analysis hiatus? The answer is no because each USCAR partner used its own system models to fully support their individual in-house PNGV development programs and in a limited way, the overall PNGV program. These in-house system models are not fully shared between the three USCAR partners because they are deemed to be of competitive significance and hence, proprietary.

The claim by each of the USCAR partners as to what is and what isn't competitive is critical to the degree of information sharing and consequently, the extent of the R&D leverage achievable in the PNGV program. The difference between pre-competitive and competitive information is an extremely difficult line to define. In general, it is my view that competitive technology advantages are short-lived because the industry quickly converges to a state of technological parity. My observation is that the USCAR partners are overly sensitive or perhaps too optimistic over the real competitive advantages provided by their individual technologies which they elect to classify as proprietary.

It is clearly not for our Committee to dictate to the USCAR partners what should or should not be shared. Nevertheless, the NRC Committee observes that excessive proprietary classification by the individual USCAR partners in the PNGV context can impede the program's progress, increase the degree of redundancy which results in a reduction of R&D leverage per dollar invested and thus defeats an objective of PNGV.

Technology Assessment

I would like to review with you a summary chart (Table H-1) which provides our Committee's view, in a very broad sense, of the potential of the major technologies under consideration and development by the PNGV program

At the present time it is considered highly likely that PNGV candidate vehicles will need to recapture vehicular kinetic energy during braking in order to meet the 80mpg fuel economy target. The simplest known technique for this is through electrical regeneration and energy storage. This, in turn, leads to a basic decision that the drivetrain will be some form of hybrid-electric. The three principal energy converters under consideration are diesel engines, turbines and fuel cells which would operate in a hybrid-electric mode. The leading energy storage candidate systems are either electro-chemical, namely batteries, or electro-mechanical, namely flywheels.

Another major consideration is the trade-off between vehicle weight reduction and improvement in energy conversion efficiency. Hence, lightweight alternate materials, such as polymer-based composites, aluminum and lightweight high alloy steels are important candidates.

This chart (Table H-1) summarizes the various technology candidates being developed, the critical technological barriers, the ability of the technology to meet the cost objectives and the likelihood of meeting PNGV schedules. Two further columns show the overall potential of the individual technologies regardless of the schedule and the basic current program needs.

In reviewing the energy conversion or powertrain part of the vehicle, the Direct Injected Compression Ignition, or diesel engine, is rated as having the highest probability of meeting the PNGV objectives. The critical research challenge is to develop an effective and durable catalyst for controlling emissions of Nitrogen Oxides (NOx). More efforts and funds are needed to meet this challenge within the PNGV schedule.

The fuel cell and turbine are rated equally at this point in time. In the absence of unexpected short-term breakthroughs, neither system is expected to meet vehicle cost or schedule requirements of the PNGV program. On a long-term basis, the fuel cell has very attractive performance and emission characteristics. However, it will not be initially competitive until an economical fuel reformer is developed to generate hydrogen on-board the vehicle.

In terms of electro-chemical energy storage, most of the same problems exist which prevent the conventional electrical vehicle from becoming a viable and economic form of personal transportation in the near future. There are a significant number of R&D programs devoted to battery breakthroughs, however, at the same time the committee feels that there needs to be more focus and added resources.

The flywheel as an electro-mechanical energy storage device holds promise, however, there are some concerns as to the safety of the device in vehicle crash situations. As with batteries, the Committee feels that there needs to be more focus and added resources on flywheel R&D.

The final major element is materials. The PNGV Program has set as an objective a vehicle weight reduction of up to 1400 pounds or 40%. It is unlikely that this weight reduction can be achieved with steel and it is equally unlikely that it will be achieved with polymer composites for reasons of cost. Aluminum is very attractive and production vehicles are currently being built with aluminum bodies. However, the most probable outcome will be the use of all of these materials in one form or another.

PNGV Response to NRC Recommendations

Turning to your second question as to how responsive have the PNGV partners been to the Committee's reports and recommendations. In general, the PNGV partners have been responsive and have found many of our Committee's recommendations helpful. As you can expect, this does not mean that they agree with all of our positions or accept all our recommendations. The nature of the PNGV partnership, namely one half competitive industry and the other half a broad coalition of a wide array of government entities, requires our Committee to fully understand and appreciate the environment in which the program is being conducted when providing recommendations.

Our Committee's Phase II report contains twenty recommendations for the PNGV program. Most of which PNGV has addressed and accepted. Some are considered outside the scope of the program at the present time; for example, the impact of the ultimate vehicle design on the national infrastructure related to vehicles and highway transportation.

Foreign Technology

The final topic I would like to discuss is foreign technology and foreign competition. Even though PNGV is an American program for the benefit of American taxpayers, it is mandatory that PNGV constantly evaluate global automotive technology developments. This chart (Table 9-1) is a crude first approximation of the relative position of the United States, Europe and Japan in the development of critical PNGV technologies. As can be seen, the United States is not rated first in each of these technologies and in fact, is rated 2nd and 3rd in the critical areas of lightweight materials and compression ignition engines.

The PNGV has responded to these observations and it is the Committee's understanding that they are devoting more attention to foreign technology assessment and availability.

I would now like to introduce Dr. Robert Hirsch of our NRC PNGV Committee to provide some views on PNGV organization and management.

Thank you.

TABLE H-1 Potential of PNGV Candidate Technologies

Major Subsystems	Critical Technical Barriers	Cost[a]	Likelihood of Meeting Schedule[a]	Overall Potential Regardless of Schedule[b]	Basic Needs
Hybrid Drivetrain Power Sources					
DICI	NO_x catalyst	Low	High	High	Resources
Fuel cell	Fuel processor/reformer Fuel storage	High	Low	Medium	Breakthroughs
Turbine	Structural ceramics Exhaust heat recovery	High	Low	Medium	Breakthroughs
Energy Storage					
Battery	High cycle life	Medium	Medium	Medium	Resources, focused R&D
Ultracapacitor	Efficiency Self-discharge Safety	Medium	Medium	Medium	Breakthroughs, resources
Battery/ultracapacitor	Integration Safety	Medium	Medium	High	Breakthroughs, resources
Flywheel	Safety	High	Medium	Medium	Resources, focused R&D
Power electronics	Efficiency	High	High	High	Resources
Lightweight Structural Materials					
Composite	High volume manufacture Crashworthiness	High	Low	Medium	Resources, focused R&D
Aluminum	High volume manufacture Joining	Medium	High	High	Focused R&D
Steel	Weight	Low	Medium	Medium	Focused R&D

[a] High cost is a barrier, as is low likelihood of meeting the PNGV schedule.

[b] Long-term potential beyond 2004.

TABLE 9-1 Preliminary Ranking of U.S., European, and Japanese Advanced Automotive Technologies

Technology	U.S.	Europe	Japan
Internal combustion, compression ignition engine	3	1	2
Internal combustion, spark ignition engine	2	2	1
Gas turbine	1 (systems)	1 (systems)	1 (components)
Fuel cell	Immature technology—no ratings assigned		
Flywheel	1	1	3
Battery	1 (high energy)	2	1 (high power)
Ultracapacitor	3	3	1
Lightweight materials	2	1 (aluminum)	1 (high-strength steel)

Note: 1 = highest ranking; 3 = lowest ranking

Mr. EHLERS. Dr. Hirsch.

STATEMENT OF DR. ROBERT L. HIRSCH, PRESIDENT, THE ENERGY-TECHNOLOGY COLLABORATIVE, INC., AND CHAIRMAN OF THE SUBGROUP ON PROGRAM MANAGEMENT OF THE NATIONAL RESEARCH COUNCIL COMMITTEE TO REVIEW THE RESEARCH PROGRAM OF THE PNGV

Dr. HIRSCH. Good afternoon. I am Dr. Robert Hirsch, President of the Energy Technology Collaborative, Incorporated, a research and development brokerage for the electric power industry.

I appear before you today as the Chairman of the Subgroup on Program Management of the Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles of the National Research Council Board on Energy and Environmental Systems.

My brief remarks will highlight some of the points that our Committee made in Chapter 9 of our second report published in March of 1996 and which Trever Jones has just so ably outlined for you.

Management of the PNGV program represents a major challenge requiring technological innovation, integration of complex elements, minimum product cost, high product reliability, environmental protection, passenger safety and enhanced competitiveness. The involvement of the three major U.S. auto companies, Chrysler, Ford and General Motors, which are traditionally competitors rather than collaborators, together with several government agencies and national laboratories adds an additional major challenge.

During the past year the PNGV has solidified its technical organization structure. Central to the organization are the technical teams responsible for R&D on candidate subsystems. Technical oversight and coordination are provided by the Vehicle Engineering Team. The teams are staffed by representatives from government and industry. Our Committee determined that these teams appear to be effectively organized and working towards specific objectives.

The PNGV Technical Roadmap provides an overall program schedule as well as schedules for the various technology teams. All appears to be in line with program objectives as would be expected for a roadmap in its infancy.

A major issue of concern to our Review Committee is the level of funding for the government part of the PNGV program. The PNGV program plan included estimates of required government funding levels which were to grow over time. These levels were considered essential to program success and were based in part on the expectation that the government partners would fund longer-term, higher-risk technologies while the industry partners would fund short-term, lower-risk technologies.

It is now known that the FY 1996 federal budget for the various PNGV programs was reduced below that requested. Because the final PNGV budgets were not known when our second report was prepared, the Committee was unable to judge the impact of the reductions on the overall PNGV schedule.

Without question, the budget reductions will delay milestone achievement and increase the risk associated with meeting the technical objectives unless a reallocation of resources to the most promising candidate subsystems occurs within the PNGV program.

The problem is compounded by the fact that the government program manager does not have the authority to redeploy existing funds to the highest priority projects.

As noted in our Committee's second report and as recommended in its first report, the Committee continues to believe that with respect to detailed program management the industry partners would be well served by having a single technical director in USCAR. The absence of such technical leadership has resulted in the USCAR members of the PNGV being unable to use the leverage of an integrated organization in pursuit of the program goals.

Many of the current program difficulties—the delay in starting systems analysis work, the complexities resulting from the decision to develop separate concept vehicles, and the very limited amount of time being spent on USCAR/PNGV business by some staff—could all be addressed more effectively if the USCAR members of the PNGV formed an integrated working group under a single technical director. The responsibilities of a USCAR technical director would include establishing appropriate operating procedures and control mechanisms.

On the government side our Review Committee continues to consider strong central program management essential to the success of the program. The government currently lacks an effective program management organization and is also in need of a chief technical officer to provide direction and leadership to the many federal organizations supporting PNGV.

The program management office, located in the Department of Commerce, operates more as an information office than as a program director's office. The staff of the program management office has essentially no authority to impact the program other than through personal persuasion. PNGV program management at the DOE similarly is not empowered to directly influence the array of federal projects potentially contributing to the PNGV initiative. The majority of these projects were initiated before the advent of the PNGV program and therefore respond in varying degrees to PNGV needs.

One result of this management arrangement is that when the technology down select occurs in 1997 PNGV management on the government side will have little or no ability to participate actively in that process or to redeploy funds from less significant projects to more important ones. Consequently, high-priority projects may not be adequately funded, and projects of less relevance to PNGV, albeit possibly justified for other purposes, may be funded.

Finally, the PNGV plan does not show regular program reviews either by participants or through independent reviews. Both National Research Council reports on the PNGV research program, the first issued in October of 1994 and the second in March of 1996, have been acknowledged to be extremely valuable in providing important findings and recommendations. Our Committee suggests that regular program reviews be explicitly scheduled in the PNGV program plan and that an appropriate budget be earmarked for this purpose.

Three of our Committee's important recommendations in its second report are as follows:

One, our Committee still strongly recommends that the partners in USCAR appoint a single technical director as a way of benefitting from the leverage of an integrated organization in pursuit of PNGV goals.

Two, our Committee reiterates its earlier recommendation that senior management in the Departments of Commerce and Energy install a management structure with appropriate authority and responsibility as soon as possible and ensure strong capable staffing. This structure should include a chief technical officer to provide technical direction to the wide array of government technical activities. The role of the chief technical officer becomes even more critical in the absence of a single USCAR technical program director.

Three, and, finally, to be successful a complex development program such as PNGV must have well-defined plans and objectives, adequate resources and sufficient funding. It is incumbent upon both USCAR and the government to ensure that adequate resources for the PNGV program are provided in a timely manner and used effectively in overcoming the critical barriers in achieving PNGV goals.

That concludes my prepared remarks, Mr. Chairman.

Mr. EHLERS. Thank you very much. I appreciate those remarks, particularly about management, and the recommendations.

[The prepared statement of Dr. Hirsch follows:]

TESTIMONY

before the Subcommittee on Energy and Environment
of the House Science Committee

on the

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES (PNGV)

by

DR. ROBERT L. HIRSCH

President, The Energy Technology Collaborative, Inc.,
and
Chairman of the Subgroup on Program Management of the National Research Council
Committee to Review the Research Program of the Partnership
for a New Generation of Vehicles

July 30, 1996

Good afternoon. I am Dr. Robert L. Hirsch, President of the Energy Technology Collaborative, Inc., a research and development brokerage for the electric power industry. I appear before you today as the Chairman of the Subgroup on Program Management of the Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles of the National Research Council, Board on Energy and Environmental Systems. My brief remarks will highlight some of the points that our Committee made in Chapter 9 of its second report, which was published in March, 1996 and which Trevor Jones has just so ably outlined for you.

Management of the PNGV program represents a major challenge, requiring technological innovation, integration of complex elements, minimum product cost, high product reliability, environmental protection, passenger safety, and enhanced competitiveness. The involvement of the three major U.S. automotive companies Chrysler, Ford, and General Motors which are traditionally competitors rather than collaborators, together with several government agencies and national laboratories adds an additional major challenge.

During the past year, the PNGV has solidified its technical organization structure. Central to the organization are the technical teams responsible for R&D on candidate subsystems. Technical oversight and coordination are provided by the Vehicle Engineering Team. The teams are staffed by representatives from government and industry. The committee determined that these teams appear to be effectively organized and working towards specific objectives.

The PNGV Technical Roadmap includes an overall program schedule as well as schedules for the various technology teams. All appears to be in line with program objectives as would be expected for a roadmap in its infancy.

A major issue of concern to our review committee is the level of funding for the government part of the PNGV program. The PNGV program plan included estimates of required government funding levels, which were to grow over time. These levels were considered essential to program success and were based, in part, on the expectation that the government partners would fund longer term, higher risk technologies; the industry partners would fund shorter term, lower risk technologies.

It is now known that the FY 1996 federal budget for the various PNGV programs was reduced below that requested. Because the final PNGV budgets were not known when the second report was prepared, the committee was unable to judge the impact of the reductions on the overall PNGV schedule. Without question, the budget reductions will delay milestone achievement and increase the risk associated with meeting the technical objectives, unless a reallocation of resources to the most promising candidate subsystems occurs within the PNGV program. The problem is compounded by the fact that the government program manager does not have the authority to redeploy existing funds to the highest priority projects.

As noted in the committee's second report, and as recommended in its first report, the committee continues to believe that, with respect to detailed program management, the industry partners would be well served by having a single technical director in USCAR. The absence of such technical leadership has resulted in the USCAR members of the PNGV being unable to use the leverage of an integrated organization in pursuit of the program goals. Many of the current program difficulties--the delay in starting systems analysis work, the complexities resulting from the decision to develop separate concept vehicles, and the very limited amount of time being spent on USCAR/PNGV business by some staff--could all be addressed more effectively if the USCAR members of the PNGV formed an integated working group under a single technical director, rather than being a team in name only. The responsbilities of a USCAR technical director would include establishing appropriate operating procedures and control mechanisms.

On the government side, our review committee continues to consider strong central program management essential to the success of the program. The government currently lacks an effective program management organization and is also in need of a chief technical officer to provide direction and leadership to the many federal organizations supporting PNGV. The program management office, located in the DOC, operates more as an information office than as a program directors office. The staff of the program management office have essentially no authority to impact the federal program other than through personal persuasion. PNGV management at the DOE similarly is not empowered to directly influence the array of federal projects potentially contributing to the PNGV initiative. The majority of these projects were initiated before the advent of the PNGV program and, therefore, respond in varying degrees to PNGV needs.

One result of this management arrangement is that, when the technology down select occurs in 1997, PNGV management on the government side will have little or no ability to participate actively in that process or to redeploy funds from less significant projects to more important ones. Consequently, high priority projects may not be adequately funded, and projects of less relevance to PNGV, albeit possibly justified for other purposes, may be funded.

Finally, the PNGV plan does not show regular program reviews either by the participants or through independent reviews. Both NRC reports on the PNGV research program, the first issued in October, 1994 and the second in March, 1996, have been acknowledged to be extremely valuable in providing important findings and recommendations. The committee suggests that regular program reviews be explicitly scheduled in the PNGV plan and that an appropriate budget be earmarked for this purpose.

Three of the Committee's important recommendations in its second report are as follows:

1. The committee still strongly recommends that the partners in USCAR appoint a single technical director as a way of benefitting from the leverage of an integrated organization in pursuit of PNGV goals.
2. The committee reiterates its earlier recommendation that senior management at DOC and DOE install a management structure with appropriate authority and responsibility as soon as possible and ensure strong, capable staffing. This structure should include a chief technical officer to provide technical direction to the wide array of government technical activities. The role of the chief technical officer becomes even more critical in the absence of a single USCAR technical program director.
3. To be successful, a complex development program such as PNGV must have well defined plans and objectives, adequate resources, and the support of sufficient funding. It is incumbent upon both USCAR and the government to ensure that adequate resources for the PNGV program are provided in a timely manner and used efficiently in overcoming the critical barriers to achieving PNGV goals.

Mr. EHLERS. Finally, we will turn to Professor Daniel Sperling.

I will interject that I have received word that we will have votes on the floor very soon. It appears there will be two votes, and for those of you who are not familiar with the Congress, when the bells ring we have 15 minutes to be get there, and there will probably be a 15-minute vote followed by a five-minute vote. So that's likely to take at least 20 to 25 minutes out of our hearing.

Professor Sperling.

STATEMENT OF PROFESSOR DANIEL SPERLING, DIRECTOR, INSTITUTE OF TRANSPORTATION STUDIES, UNIVERSITY OF CALIFORNIA, DAVIS

Professor SPERLING. Thank you. I will be brief.

My name is Dan Sperling, and I'm Professor of Transportation Engineering and Environmental Studies and founding Director of the Institute of Transportation Studies at the University of California at Davis. The Institute that I direct administers over $7 million in research contracts and grants, the majority of which involve advanced vehicle technologies and fuels.

I've chaired or been a member of several National Research Council committees on vehicle technologies and fuels, though not this one that is represented at the table next to me, and I have authored or co-authored five books and over a hundred papers and reports on these topics. And I also regularly consult with and advise many major energy and automotive companies and government agencies in the U.S. and abroad.

What I'll do here is just briefly summarize my written testimony.

Mr. EHLERS. Please don't rush. We will have a few minutes after the bells ring to get to the votes. So feel free to take your allotted time.

Professor SPERLING. Thank you.

Well let me begin by saying that I do endorse the goals of PNGV. Technology is near at hand to achieve huge and rapid reductions in energy use and pollution, and government must play an instrumental role if those technologies are to be developed and commercialized.

I also believe PNGV has been a step in the right direction. It has already made positive and important contributions. It has helped focus the DOE R&D programs, it has eased somewhat the adversarial relationship between automakers and regulators, it has helped the Big Three automakers close the gaps with European companies in advanced diesel technology, and it has also stimulated advances in fuel cell technologies, and these are important achievements.

But that's the past. PNGV is now at a critical juncture. Unless PNGV is reorganized and refocused I believe it will no longer serve the country well. My concern is that PNGV as presently constituted will not provide the leadership this country needs. In fact, it may be counterproductive.

PNGV has two fundamental problems. The first is the procedural requirement that technology to be used in the 2004 production prototypes must be selected by end of 1997, what we've heard referred to as down selection. At first glance this requirement seems reasonable. It assures that industry will stay on track to meet the 2004 deadline. The actual effect will be perverse. The problem is that 1997 is rapidly approaching and only one technology will be picked by each of the three companies. What will it be?

Given the risk adverse nature of the PNGV managers in both industry and government, all indications are that it will be a direct-injected diesel engine combined with an electric driveline and a small battery pack. This choice is disappointing for several reasons: (1) Diesel engines inherently emit large amounts of nitrogen oxide emissions and particulate matter, the two most severe air pollution threats facing the country; (2) The industry is already well along in developing advanced diesel engines for the European market; and (3) It ignores other potentially more promising technologies, such as fuel cells, and relegates them to the back burner.

The choice of diesel hybrids could also be an economically disastrous mistake. It ignores the worldwide trend and desire for increasingly cleaner vehicles. Pressure on the world's automakers to build cleaner vehicles is likely to intensify and not diminish. That's why diesel technology is not likely to power the next generation vehicle even in a hybrid configuration.

The second problem with PNGV is that too much of the government funds go to the Big Three automakers and their suppliers. They receive, as best as I can tell, over half the funds devoted to Goal 3, the tripled fuel economy goal. This is not the most effective means of accelerating the development and commercialization of these advanced technologies.

I believe it represents a poor investment of government funds. After all, the three automakers have little incentive to aggressively pursue triple fuel economy. Gasoline prices are lower than ever, CAFE standards are frozen and PNGV offers no carrots nor sticks.

Moreover, the amount of government R&D funding is so small relative speaking that it has little influence. The automakers receive about $60 million per year for Goal 3 research. This amount is swamped by the many billions of dollars the industry already spends on R&D annually.

And perhaps most critically much of the information on advanced vehicle technology is not shared. The three automotive companies have reportedly erected a firewall between their in-house PNGV managers and their other R&D managers so as to restrict sharing of technological breakthroughs.

General Motors, for instance, has reportedly created a proprietary in-house fuel cell program that is completely independent and parallel to their government-funded PNGV fuel cell program. Where do you think GM's major effort is going to be, in the government-funded PNGV program or in their own proprietary program?

The inescapable conclusion is that government-funded R&D has little effect on automaker efforts to develop and commercialize advanced vehicle technology.

To be blunt, after all I'm an academic and less constrained than other folks, to be blunt PNGV is not directing funds toward the right technologies nor the right organizations. As a result, our country is foregoing important economic and environmental benefits and risks losing leadership to the Europeans and Japanese. The unveiling of a fuel cell car by Mercedes-Benz on May 14th of this year and its announcement that it may be ready to sell fuel cell cars before 2010 is an indication of the global demand for efficient and clean vehicles and the intention of foreign companies to supply that technology.

I have four recommendations for restructuring PNGV.

The first one is to place renewed emphasis on cleaner and more promising long-term technologies. I would suggest removing the requirement that a single technology be down selected in 1997 and, instead, require that each of the Big Three must pursue highly efficient and low-polluting technology options, technologies that include not only fuel cells but also Stirling engines, ultracapacitors and flywheels.

The second recommendation: require that federal funds be matched at least 50/50 for these advanced technology efforts. The PNGV program now has a 50/50 overall match requirement, but it appears that most of the industry dollars are directed at PNGV Goals 1 and 2, the ones dealing with manufacturing and near-term vehicle technology. So most of the industry dollars are directed at PNGV Goals 1 and 2, which is money the Big Three and their suppliers would have spent anyway, and virtually none go to the Goal 3 activities, or at least as best we can tell based upon the information that is available.

Number three, direct a significant share of funding toward independent research centers and technology companies. Funds should be directed at independent skunkworks and research facilities, including universities and unaffiliated technology companies. This would have several benefits.

First, these other centers and companies would provide a benchmark with which to evaluate progress by the major automotive companies, and this is important for both regulatory and R&D funding purposes.

Also, support of universities and other organizations would create a broader base of expertise outside the traditional auto industry.

Also, supporting universities would assure that engineers and scientists are being trained for the automotive industry of tomorrow.

And, lastly, small entrepreneurial companies and technology companies unaffiliated with the automakers have a stronger and purer incentive to develop and commercialize environmental technology and, thus, the return on taxpayer money would be much higher.

My last recommendation is that government management for Goal 3, for the triple fuel economy, should be transferred from the Department of Commerce to the Department of Energy, and this echoes what we just heard a moment ago. The March '96 NRC review of PNGV that we just heard of criticized PNGV for lacking an effective program management organization and little or no ability to redeploy funds from less significant to more important technology developments in response to budget reductions or following technology selection.

A central cause of this ineffective management seems to be that DOE, which provides something like 95 percent of the funds for Goal 3 and virtually all of the technical expertise in this area, is shackled by having to work through many extra bureaucratic layers of decision-making. My three preceding recommendations would have a much better chance of being implemented if control of Goal 3 activities were shifted to DOE.

In closing, it's with some reluctance that I criticize PNGV, for I am firmly convinced that advanced vehicle technologies can and will play a leading role in preserving the environment. But if PNGV cannot be reformed to support more advanced and cleaner technologies and to fund independent companies and universities at a much higher level, then perhaps it should be allowed to die a peaceful death. If, on the other hand, changes are made, then substantial increases in PNGV funding would probably be a good investment of public monies.

Thank you.

[The prepared statement of Professor Sperling follows:]

Rethinking PNGV

Hearing on "Partnership for a New Generation of Vehicles:" Assessment of Program Goals, Activities, and Priorities

Testimony to US House of Representatives, House Science Committee, Subcommittee on Energy and Environment

by

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July 30, 1996

Good afternoon. My name is Daniel Sperling. I am Professor of Transportation Engineering and Environmental Studies, and founding Director of the Institute of Transportation Studies at the University of California, Davis. This Institute administers over $7 million in research contracts and grants, and is staffed by about 100 research faculty, post-doctoral scholars, and student research assistants. I oversee major research programs in electric, hybrid, and fuel cell vehicle technology. I have been deeply involved in the study of advanced propulsion technologies and alternative fuels since the late 1970s. I am founding chair of the Alternative Fuel Committee for the Transportation Research Board of the National Research Council, have participated in several National Research Council committees on energy and environmental aspects of motor vehicles, and have authored or co-authored 5 books and over 100 papers and reports on the topic.

Let me begin by saying that I strongly endorse the goals of PNGV and the need for strong government support of advanced vehicle R&D. It is clear that the automotive industry is on the threshold of a technological revolution. Technology is near at hand to achieve huge and rapid improvements in energy use and pollution reduction. But industry has little incentive to pursue many of these advanced technologies because their major benefits -- reduction of oil imports, greenhouse gases, and air pollution -- do not have value in the marketplace. And so there is a clear role for government, as a regulator and supporter of advanced technology R&D.

There is another important reason for government to support these advanced automotive technologies: global competitiveness, to assure that the United States retains international leadership. Other countries seem more determined than us to develop these new technologies and advanced vehicles, for reasons I will indicate below. If we sit passively by, the nation risks losing millions of jobs and billions of dollars in economic growth.

PNGV has made some positive and important contributions: it has helped focus DOE R&D programs; eased somewhat the adversarial relationship between automakers and regulators through increased communication and coordination; helped the Big 3 close a gap with European companies in advanced diesel technology, and stimulated advances in fuel cell technologies. These are important achievements. But that's the past.

PNGV is at a critical juncture. Unless it is reorganized and refocussed, it will no longer serve this country well. My concern is that PNGV, as presently constituted, will not provide the leadership this country needs. In fact, it may be counterproductive

PNGV has two fundamental problems. The first is its procedural requirement that technology to be used in the 2004 production prototypes must be selected by the end of 1997. At first glance this requirement seems reasonable: it assures that industry will stay on track to meet milestones and the 2004 deadline. The actual effect will be perverse. Because 1997 is rapidly approaching and only one technology will be picked (by each of the 3 companies), risk-averse PNGV managers in the Big 3 and in the federal government are expected to favor incrementalism over leapfrogging. That is, organizational and political realities push them toward selecting modest enhancements of conventional technologies, and away from more advanced technologies, such as fuel cells, that are riskier but potentially far more promising.

It appears that the three automotive companies, with government concurrence, will select a direct-injected diesel engine combined with an electric driveline and a small battery pack This choice is disconcerting for several reasons: 1) Diesel engines have inherently high NOx and particulate emissions, 2) industry is already well along in developing these advanced diesel engines for the European market; and 3) other potentially more promising technologies would be pushed aside.

Based on conversations with federal officials and corporate executives, I suspect that the willingness to embrace diesel technology is premised on a perception that America's air quality problem is mostly solved. While it is true that pollution has subsided in most American cities, the Detroit-Washington belief that pollution will not be a factor in defining the next generation vehicle could be tragically mistaken. Coming from California, I may be more sensitive to the fact that demand for cleaner air is not a California-specific phenomena. Indeed, not only do many US cities continue to experience unhealthy air and many Americans continue to demand clean air, but in European and Asian cities the demand for cleaner air is becoming ever stronger. Pressure on the world's auto industry to build still cleaner vehicles is likely to intensify That is why diesel technology is unlikely to power the next generation vehicle, even in a hybrid configuration. California is not an outlier in terms of pollution and the desire for pollution-free vehicles.

The second fundamental problem with PNGV is that the apparent policy of directing most PNGV-related government funds to the Big 3 and their suppliers is not the most effective means of accelerating the development and commercialization of advanced technologies. It represents a poor investment of government funds, for the following reasons:

- The Big 3 and their principal suppliers will continue to develop and commercialize incremental-type technologies, regardless of government funding -- and even many truly advanced technologies -- for a variety of reasons, not the least of which is California's zero emission mandate. Indeed, virtually all the technical accomplishments of PNGV listed in their glossy brochure published this month (July 1996) appear to be the results of ongoing efforts by the Big 3 and their suppliers

- Because fuel prices are low and CAFE standards frozen, the Big 3 have little incentive to aggressively pursue the tripled fuel economy goal. This is the real-world political and economic context for PNGV; no carrots, no sticks. The result is that Big 3 management places little value on government support for longer term, riskier PNGV technologies.
- The $60 million dollars or so in advanced vehicle R&D sent annually to the auto industry by DOE has little influence on Big 3 priorities and R&D activities, partly for the above reasons, and partly because the amount is tiny relative to the many billions in R&D they already spend annually.
- The highly competitive automotive companies are understandably reluctant to share information on technological breakthroughs. As a result, the three automotive companies have reportedly erected a firewall between their in-house PNGV managers and their other R&D managers. For example, GM has reportedly created a proprietary in-house shadow fuel cell program that is completely independent and parallel to their government-funded PNGV fuel cell program By implication, whenever GM (or any automaker) is serious about a technology, it will channel its development efforts away from PNGV to assure complete confidentiality. That GM behaves this way even with fuel cells, the most far-off of the major PNGV technologies, is further evidence that government funds are not valued highly.

The inescapable conclusion is that government-funded R&D plays a small role in automaker development and commercialization efforts and that government awards to the Big 3 and their suppliers are not generating as much technological development as might be expected.

PNGV is not directing funds toward the right technologies nor the right organizations. As a result, our country is foregoing important economic and environmental benefits and risks losing leadership to the Europeans and Japanese. The unveiling of a fuel cell car by Mercedes-Benz on May 14, and their announcement that they may be ready to sell fuel cell cars by 2010 is an indication of global demand for energy efficient and environmentally benign vehicles, and the intention of foreign companies to supply that technology.

I have three recommendations for more effectively leveraging government R&D funds and assuring that PNGV continues to accelerate the development and commercialization of advanced automotive technologies.

1. Renew emphasis on cleaner and more promising long term technologies.

Remove the requirement that a single technology be "down-selected" in 1997. Instead, require that each of the Big 3 pursue highly efficient and low-polluting options, such as fuel cells, Stirling engines, ultracapacitors, and flywheels. And require that the federal funds be matched at least 50/50 for these advanced technology efforts. The overall PNGV program now has a 50/50 match requirement, but it appears that most of the industry dollars are directed at PNGV goals 1 and 2 (improvements in near-term vehicle technology and manufacturing processes), which is money they would have spent anyway, and virtually all of the goal 3 activities (tripled fuel economy) are being paid for by government (though lax cost accounting procedures make it impossible to confirm)

2. Direct a significant share of funding toward independent research centers and technology companies.

Funding of independent skunkworks and research facilities, including universities, and unaffiliated technology companies would have several benefits: i) these other centers and companies would provide a benchmark with which to evaluate progress by the major automotive companies, for regulatory and future R&D funding decisions; ii) support of universities and other organizations would create a broader base of expertise outside the traditional auto industry; and iii) small entrepreneurial companies and technology companies unaffiliated with the automakers have a stronger and purer incentive to accelerate technology development and commercialization.

3. Reassign Government Management for Goal 3 to DOE

The March 1996 NRC review of PNGV stated that the "government lacks an effective program management organization, little or no ability to redeploy funds from less significant to more important technology developments in response to budget reductions or following technology selection" (p. 3). A central cause of this problem seems to be that DOE, which provides and controls over 95% of the funds for goal 3 (tripled fuel economy) and virtually all the technical expertise in this area, is inhibited and distracted by unneeded layers of policymaking and bureaucratic decisionmaking. My two preceding recommendations would have a much better chance of being implemented if control of goal 3 activities were shifted to DOE.

It is with some reluctance that I criticize PNGV, for I am firmly convinced that advanced vehicle technologies can and will play a leading role in preserving the environment. But if PNGV cannot be reformed to support more advanced and clean technologies and to fund independent companies and universities, then it should be allowed to die a peaceful death. On the other hand, if changes are made, then the argument for substantial increases in PNGV funding becomes more compelling.

Mr. EHLERS. Thank you, Professor Sperling, and thank you to everyone on the panel for your comments. They have been very useful.

I have been informed that there has been some delay in progress on the floor and so we may have a little more time than we thought before we hear the bells ringing.

A few matters of business. Without objection, I will order that the written testimony of all the panelists will be entered into the record as well as a statement for the record by Dr. Jay Keller, Hydrogen Program Manager of Sandia National Laboratories.

[The prepared statement of Dr. Keller is in Appendix III.]

Mr. EHLERS. We will now turn to questioning of the panel by those who are present.

I pick up a thread running through the testimony of those who are not from the automobile industry. Mr. Jones, you mentioned the problem of the proprietary issue and the feeling that information is not being shared as freely as it should perhaps be. That was echoed by the last witness. In addition, Dr. Hirsch, you pointed out some of the management problems.

Generally there seems to be a thread of concern here that, first of all, the program is not being managed as efficiently as it should be and perhaps it's not being managed by the right agency or the right people and, secondly, that there is not as close a cooperation between the Federal Government and the private sector as there should be, and that particularly there is not good cooperation between the PNGV research done by industry and the private research done by the industry.

I find that a matter of real concern. I'm not sure we want to get into rewriting the whole act, but certainly the purpose of the panel is to try to determine what problems there may exist.

First, just a very simple question. Professor Sperling, your recommendation that more money should to go universities, is this because you're proud of universities or because you have a self-interest in getting more money? I have some sympathy for your position being a former academic myself, but I would like for you, if you can, clarify your motives to the extent you're able to.

Professor SPERLING. Well of course I probably always have the same motives that everyone else does that wants to strengthen some of the activities they're involved in, but I do believe very strongly that there is a real problem here in that there are not the people being trained in the universities to work on these technologies.

I, for instance, would love to hire a faculty member to head up our research in the fuel cell area, an electro-chemist type person. There are essentially almost none being turned out around the country that are suited to be hired to be running a program like that, and this cuts across in several different areas. So we just aren't turning out—we aren't doing the research in the universities nor training the people needed in the universities to play this kind of role that will be necessary in the future.

Mr. EHLERS. Thank you.

Mr. Mull.

Mr. MULL. I would just like to point out that one of the things that we did to get university involvement was Ford, GM and

Chrysler and the Department of Energy did have a future car competition. We had 40 schools submit proposals and 12 were chosen. We recently had the first competition at Ford Motor Company about a month ago. I will also admit that the industry side was somewhat skeptical of having a competition like this.

We provided four Tauruses, four Luminas and four Concordes to the 12 schools and seed money for them to go as far as they could in improving the fuel economy under a set of rules. We had the competition, and I have to tell you we were amazed at what a tremendous training opportunity it provided to the students. They were very impressive, and the work they did was impressive. The professors at the universities were extremely helpful and also impressive.

One of those schools was Professor Sperling's school, Cal Davis, and Dr. Franks was a key member of their team at that school.

So we are doing that, and we are training people, and we are hiring these people as well.

Mr. EHLERS. One of the biggest factors of course is that you're battling in laws of summa dynamics at every term. That's one of the basic problems of the internal combustion engine, including the diesel version. As efficient as that is, it's still a real problem compared to some other programs.

Mr. MULL. Well we would like to also comment on what was said about diesel engines. The diesel technology that we're working on is leapfrogging the direct injection diesel technology that's going on in Europe. In fact, one of the members of that technical team was with EPA, and he described it as a significant leapfrog over what is going on. We're not just trying to catch up, but we're moving ahead.

In one of the diesel programs that's being developed, we're actually going to very lowest of tier two emissions in the ultra-low emission vehicle standards in California. That's a very, very low NOX level and an extremely low particulate level.

Mr. EHLERS. Of course one good way to deal with the NOX level would be to use hydrogen in combination with oxygen if you would like to carry both of those on a vehicle.

[Laughter.]

Dr. Hirsch, it seems to me you had some very pertinent recommendations regarding management changes that should go into this. Let me ask you, and I'm not sure what experience you have with government, do you think that the management problems that you identified can be solved within a government/industry cooperative venture like this, or do you think they're endemic to that type of structure?

Dr. HIRSCH. First of all, I spent nine years in government and a number of years in this room also, not only on this side of the table, but on the other side of the table in the past. No, it is entirely possible to manage this program effectively in the Federal Government. There is no question about that in my opinion.

The problem is, and here I'm stating personal opinion as opposed to Committee opinion, the problem is that the way things were set up in the government was as a loose confederation of not only projects, but a loose confederation of people.

For instance, you'll notice that Rob Chapman, who is essentially the head of the program, introduced himself as Chairman of the government's PNGV Technical Task Force. Most people consider him the head of the program, and yet he does not have the authority to run the program directly. He is put in a position where he has to try to coax people within the government establishment to do the things that he deems are important, and the same thing is true with the management at the Department of Energy.

In other words, for reasons that we don't understand, and I don't personally understand, responsibilities were given, but the authority was not given commensurate. So that the current structure is simply not adequate to run a program that is as demanding as this one is.

Mr. EHLERS. Thank you.

Mr. Mull.

Mr. MULL. We've spent a lot of time on that issue both on the industry side and on the government side. I mean, you heard us say that we're not perfect. You know, the government is the government and we live in a democracy. I think we work very hard to work together as a team, both on the government side and the industry side, to be as effective as we possibly can recognizing that we have separate agencies. We all would like to have more authority. You know, independent of the partnership we would like to have more authority to get things done, but that's just not the way things work.

We think that a lot of the problems that the Peer Review Committee saw when they did the report are improving tremendously. On the industry side, the one technical director, we simply do not agree that one technical director is appropriate. The three of us work together as a team. If we added another person above us, he or she could not be empowered and it would be another layer of bureaucracy. So we operate together and we make decisions together. We work in our separate companies and we think we're being effective.

Mr. EHLERS. Mr. Jones, you're probably the only one at the table who has had authority commensurate with responsibility when you ran Libbey-Owens-Ford.

[Laughter.]

I would appreciate your perspective on this dilemma.

Mr. JONES. The way in which Bob Mull has—and excuse my voice, I'm suffering from something, but it has nothing to do with this room.

Mr. EHLERS. We are, too, most of the time.

[Laughter.]

Mr. JONES. If any one of these automotive companies, and I should tell you I worked for General Motors for 20 years, and in fact ran their advanced engineering organization. If any one of these organizations organized a project they would have a single platform director or a single technical director for a project like this. So obviously if this was my company, I would have one guy that I would hold responsible for what's going on in that project, and likewise in the government. In my mind it's the only way to run a program.

They have said they disagree with us, and that is fine. I think our Committee will not pursue that in the next round, but we will base our findings at the end of the year on the results that they produce within the type and style of organization that they have.

Mr. EHLERS. Well thank you. My time has expired. I appreciate the comments and the testimony that has been given here.

Congresswoman Rivers.

Ms. RIVERS. Thank you, Mr. Chair.

In listening to the testimony of the first panel and this one as well, it's very clear to me that somebody is going to ultimately build this car. Whether it's Europeans, whether it's Japanese, whether it's Koreans or whether it's us, somebody is going to put together a fuel efficient car, and frankly I would like it to be Americans. And the fact that I have 29,000 auto workers in my district has nothing to do with my feelings on this. But the thing I am concerned about is that our focus, particularly in this group, seems to be more on what we're doing exclusively as opposed to what we are doing relative to our competitors.

Tim Roemer started his comments earlier by talking about the Olympics and making an analogy between the things we never thought possible in terms of physical endeavors several years ago and now being available.

I would draw people's attention to another dynamic that's taking place at the Olympics right now, and that is that the American audience is so focused on American performers that they are routinely overlooking the skill of non-American performers and they're getting beaten and they're getting surprised when the winner was running faster in another lane than the American was, and I don't want to see us have that happen here.

I have a question, and it's a similar question both for Mr. Rosenfeld, Mr. Mull and Mr. York and for Professor Sperling, but with a twist for Professor Sperling. If we eliminated the program, and I'm willing to go along that we need to make some changes, but let's say we eliminated the program and we said you three are going to compete fully with one another, what would that do to the cost of the ultimate product and what would that probably do to the time frame in which that could be produced?

Mr. MULL. If we eliminated the program from the government side?

Ms. RIVERS. Yes, completely eliminated it and you folks were all three on your own.

Mr. MULL. Well I think our industry has gone on record that we support efforts to balance the budget. But if we eliminated all budget for the PNGV, I think that we would continue to work on the technologies that we've identified. That would not stop.

Ms. RIVERS. Collaboratively or independently.

Mr. MULL. Collaboratively and independently, both.

Ms. RIVERS. So there would be more redundancy.

Mr. MULL. It has started, and I don't think we would stop that. I think Professor Sperling is absolutely right, and you saw Mr. Jones' chart. A lot of activity is going on in the world in looking at these technologies. So that would not stop. Certainly I think the pace of technology advancement would slow. There is no question about that, and we would probably revisit our objectives, and they would not be as aggressive as they are.

I guess we would like to emphasize as part of the answer that, you know, if we want significant advances in fuel efficiency, and I think we do want that, the best way to do it is to work together on it, the government and the industry, the government's technical resources. The best thing to do is work on basic research that provides commercially viable technologies that don't distort the market.

Mr. ROSENFELD. And to the point that you made about government involvement, we would continue to be in the race as three separate companies. We know that collaboration between government and industry is not a dirty concept in Asia and in Europe, and those competitors will continue to progress at a faster pace than we would. Collaborating with government together in a uniquely American approach, which we've established here, puts us in the forefront we believe. We would continue in the race, but we think we would be at the finish line probably later than the gold medalists to use your analogy.

Ms. RIVERS. Intuitively it would also seem that if you are no longer sharing technology, and the companies have to duplicate the research in each of the three companies, that the costs are going to rise as well.

The twist on it for you, Dr. Sperling, is the issues that you raised, the four issues that you raised. Without a program like this, you know, if we eliminated the program, would any of those things happen on their own, and what would be the effect on the time we would be able in this country to produce the product we're looking for, the dollars, and could we even think about doing it without involving the Big Three in some way?

Professor SPERLING. Well the way I see it is that the investment, the money going to the Big Three and their suppliers when controlled by them is getting relatively little return, and I pose as an example, for instance, a company, Ballard, a fuel cell company in Vancouver. They received considerable government funding, not from the U.S. Government, but from the California governments and Canadian governments, and they've developed what's essentially the leading fuel cell technology for vehicle applications, and they did it independently as a small entrepreneurial company.

So I think if we didn't fund the Big Three it wouldn't have much effect, but if we divert some of our funding to companies like Ballard we would see a rapid acceleration of the technologies because these companies are going to be doing a lot of work. GM has been working on fuel cells for years. But the question, is how aggressively do they push it in terms of developing it in the laboratory and bringing it closer to commercialization, and there is a lot of question about the incentive for them to do that.

Ms. RIVERS. And relative to our global competitors, sort of decentralizing, for lack of a better word, decentralizing the way that you're suggesting you think would be more effective in competing against the other countries?

Professor SPERLING. I think so. I mean the Big Three are going to buy up or buy into a lot of the technology developed by these other companies eventually anyway. That's their history, it's an effective model and it works well. It's a very competitive industry, and there are a lot of companies in Asia and Europe that face very different situations and have special expertise and have different market niches they see and respond to in different ways, and I think for that reason we are seeing and we know many of these companies are developing a variety of these different technologies, ultracapacitors and different kinds of batteries and fuel cells in a more accelerated fashion.

Ms. RIVERS. Thank you.

Mr. EHLERS. The gentlewoman's time has expired.

We have bells announcing a vote in 15 minutes, and it would be very nice if we could wrap this up so that panelists don't have to wait for us to vote and come back.

We have two more here.

Congressman Barcia.

Mr. BARCIA. I think I can be relatively brief. I would like to get some comments on the record, and perhaps we can complete the hearing before the vote is taken.

First of all, I want to thank you, Mr. Chairman, for inviting this distinguished panel of guests before the Subcommittee today and indicate how pleased I am with your testimony. While I wasn't able to hear all of the remarks, since I've arrived at the Committee I've appreciated the very specific information you've shared with the Subcommittee.

Our auto industry has been in the forefront of the world's technology, and I am sure that we all want to retain and expand upon this proud record. The Partnership for a New Generation of Vehicles program, in my opinion, is exactly the kind of action that we should be taking in the Federal Government.

A partnership between our industry, our universities and our government should be heralded as a sign of unified strength. We need the vision and technological capability of university and industry engineers, and we need the production know-how of industry, we need the government to understand the real scope and limits of technology so that the best possible policies can be adopted.

I know of the work firsthand that has been underway at Delphi Saganaw Steering Systems back in my home district in Michigan in the 5th District in cooperation with the Department of Energy for intelligent induction heating and hardening. That cooperative effort gives us new technology, a competitive edge, a sense of true accomplishment for the personnel at the facility, and the hope for keeping that plant for some time to come because it has been and will continue to be a productive, contributing member of the auto industry community at a time of intense global competition.

Now I have just one question for our distinguished panel this afternoon. Realizing the fundamental differences between the government and the private sector, could you please describe some of your experiences in working with the Federal Government.

And as a follow-up question, and I know you have to be very concise and maybe only a couple will have time to respond, do you have any recommendations to improve this already successful program?

Perhaps I could direct these two questions to Mr. Mull and perhaps Mr. Rosenfeld and Mr. York.

Mr. EHLERS. I appreciate your comments and I would ask you to be as brief as possible.

Dr. YORK. There are great opportunities that we have had working together and that we see in the future, and it's the science capabilities of the lab and their mission, and what we're doing is very complementary. You mentioned the induction heating, flame spraying is another, advanced composites is another, electronics, et cetera.

The government labs frequently have the science and the knowhow to do certain things, but we bring the volume and manufacturing capability to really translate something into a workable process. Those processes support their missions as well as ours and generate things that can be used by the entire manufacturing base in the United States. So these are probably the kind of highlights and first fruits of this payoff. The longer-bearing thing is the technology for a completely new vehicle, but these are payoffs that are featured in the accomplishments that we're seeing already.

Mr. EHLERS. Thank you very much.

Congressman Zach Wamp has joined us.

Mr. WAMP. A short quick statement, Mr. Chairman. Thank you for the time, and I'm sorry I'm late.

On behalf of the quality research that goes on at the Oak Ridge National Laboratory, and the engines of the future and lightweight materials technology for these automobiles and the applied technology demonstrated in Chattanooga where we build emissionless buses and are looking at all different kinds of vehicles, hybrid vehicles for the future we believe in what you engage yourself in.

If you would, for the record for the future, submit any documentation you have or answers to the question. Building lightweight materials, does that compromise safety? Any of you that have input on that, please just submit that to me for the record.

Mr. Chairman, if you would keep the record open for a requisite number of days so they could do that, that way we can go to vote, and thank you very much for being here today.

Mr. EHLERS. Without objection, we will do so.

I want to thank the panel very much. I'm sorry we've had to rush the last few minutes, but I'm grateful that we were uninterrupted by the votes during the majority of the hearing.

I certainly appreciate the comments offered. They'll be very helpful to us, particularly the issues raised about management, and we will pursue those as we consider the program and the funding for the next year.

Thank you very much for your participation. I deeply appreciate it.

The hearing is adjourned.

[The Subcommittee adjourned at 3:50 p.m., subject to the call of the Chair.]

[The following material was received for the record:]

Appendix I

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

OPENING STATEMENT

HONORABLE VERNON J. EHLERS

HEARING

Partnership for a New Generation of Vehicles (PNGV): Assessment Of Program Goals, Activities And Priorities

Tuesday, July 30, 1996

I welcome all the Members of the Subcommittee and the witnesses to this oversight hearing of the Partnership for a New Generation of Vehicles (PNGV). This is an interesting, ambitious and complex project involving several government agencies and the automobile industry comprised of General Motors Corporation, Ford Motor Company and Chrysler Corporation, in what is termed by the Administration as a "departure from the historical, primarily regulatory relationship between Government and the U.S. auto industry".

The PNGV program is a joint cooperative research and development program between the federal government and the United States Council for Automotive Research (USCAR), which was formed by Chrysler, Ford and General Motors. The PNGV program has its roots in the "Clean Car Initiative", which was launched by President Clinton and Vice President Gore on September 29, 1993, with three specified goals of: (1) significantly improving national competitiveness in manufacturing; (2) implementing commercially viable innovation from ongoing research on conventional vehicles; and (3) developing a vehicle to achieve up to three times the fuel efficiency of today's comparable vehicles while maintaining or improving performance and cost and meeting or exceeding current federal safety and emissions requirements. The PNGV program was established with the aim of enhancing U.S. automotive industrial competitiveness by providing a focus and pushing the boundaries of technology.

It appears that the PNGV program goals 1 and 2 were designed with a short-term outcome in mind and may have reached a stage that no longer warrants an extensive involvement by the federal government. Goal 3 presents a more ambitious and significant improvement of the automobile that Americans should drive and one that will perhaps improve the U.S. auto industry's global competitiveness. Therefore, the main focus of this hearing is on the PNGV organization, the program goals, federal government management of the program, the role of involved agencies, funding, accomplishments to date, priorities, and the level of confidence in meeting technical schedules and milestones. These points are particularly relevant to Goal 3.

Furthermore, I am interested in examining the recommendations resulting from the National Research Council's annual reviews of the PNGV program and the PNGV program's responsiveness to these recommendations. I believe strongly in the peer review process, partially because as a scientist I have been subjected to it and benefited from it. I believe that such a peer review process should become a permanent part of the PNGV operation.

The PNGV funding situation is somewhat confusing and in all fairness difficult to track. Given the complex organization and nature of the program, it is even more important to have the cooperation of all the agencies and the USCAR to determine the "real contribution" from the federal government and the actual cost-sharing by the auto industry. This would provide for a healthy and objective debate that can focus on the substantive policy and technical issues. We need to determine what are the appropriate levels and areas of government involvement and whether government funds are being invested wisely.

Putting it in a slightly different context, the question that comes up is: why in the world should the Federal Government provide a substantial amount of money, amounting to hundreds of millions of dollars, to the three largest corporations, who when combined form the largest corporations in the United States and the world, whose worst years have not equaled the annual loss of the Federal Government and whose best years put the U.S. government to shame?

At the same time, we have individuals who say this is a marvelous example of partnership between government and industry. The government plays a key role in bringing together competitors on a project where they can all bring resources to it as well as the Federal Government's resources and can make far greater progress than they could without the program.

So, the purpose of this hearing is to look at the facts, the data, the information and try to reach an appropriate judgment which will be somewhere between the two extremes which I just cited.

Now, I recognize the ranking member for any remarks he/she may have.

OPENING STATEMENT BY THE HONORABLE TIM ROEMER RANKING DEMOCRAT ON THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT HEARING ON THE PARTNERSHIP FOR A NEW GENERATION VEHICLE

July 30, 1996

Mr. Chairman, I am looking forward to this hearing. The PNGV program generates a lot of interest because most Americans, including myself, are hopeful that one day we can own a car that has tremendous performance characteristics with gas mileage that approximates 100 miles to the gallon. The benefits of such a car--to the driver from lower gas bills, to the economy from reduced transportation costs, and to the environment from curtailed emissions--are important ... and a long-time in the making.

With the Olympics going on now in Atlanta, I will draw the analogy that the goal of 100 miles to the gallon is the modern day version of the 10 second-100 meter dash. I know that before Jim Hines broke the 10-second barrier, there were many who doubted it could happen. And, regarding the 100 miles to the gallon barrier, I'd like to count myself a believer.

However, I spent some time in a car showroom recently and took note of the gas mileage that the newest models provide. To my untrained eye, the selection seemed appreciably worse than when I shopped ten years ago.

We can argue about whether the lower gas mileage prevalent on so many showroom floors is due to lax government regulation, low oil prices, or other forces. But part of the truth is that R&D has not yet produced breakthrough developments that are both marketable and safe.

I am a believer in technology development, and I surely believe that technological advancement is a better approach than strict government regulation. So I am heartened when I read that the now-defunct Office of Technology Assessment found that the high levels of fuel economy are *technically* feasible by the year 2015. But, OTA also found that producing such cars at prices that consumers will pay will be a much more difficult challenge.

The question that this Committee faces then is whether the benefits of enhanced fuel economy are worth federal investment in automotive R&D. With every federal investment, lawmakers must consider the potential for market distortion, hidden subsidies, and other problems.

However, one certainly cannot argue that the Partnership for a New Generation Vehicle has not learned from mistakes made in the past. Anticipating problems that might occur, PNGV has sought industry involvement—both monetary and directive—from the beginning, has set up a standing advisory panel at the National Research Council to monitor progress and on-going decision-making, and has set a firm long-term goals. However, it remains to be seen whether this good planning is enough. And, whether PNGV is the best approach to producing the new-American dream car.

I look forward to today's testimony. As I close, I would like to thank the Chairman for assembling such a distinguished set of panelists and thank each of the witnesses for making time in their busy schedules to appear today.

OPENING STATEMENT

THE HONORABLE JAMES A. BARCIA

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
HEARING ON
PARTNERSHIP FOR A NEW GENERATION OF VEHICLES (PNGV): ASSESSMENT OF PROGRAMS GOALS, ACTIVITIES AND PRIORITIES

JULY 30, 1996

I want you to know how pleased I am with your testimony today. Our auto industry has been in the forefront of the world's technology, and I am sure that we all want to retain and expand upon this proud record.

The Partnership for a New Generation of Vehicle (PGN) programs, in my opinion, is exactly the kind of action we should be taking. A partnership between our industry, our universities, and our government should be heralded as a sign of unified strength. We need to vision and technological capability of university and industry engineers. We need the production know-how of industry. We need the government to understand the real scope and limits of technology so that the best possible policies can be adopted.

I know of the work that has been underway at Delphi Saginaw Steering Systems in cooperation with the Department of Energy for intelligent induction heating and hardening. That cooperative effort gives us new technology, a competitive edge, a sense of true accomplishment for the personnel at the facility, and the hope for keeping the plant for some time to come because it has been and will continue to be a productive contributing member of the auto industry at a time of intense global competition.

I have just one question for our distinguished panel this afternoon. Realizing the fundamental differences between the government and private sector, describe some of your experiences working with the Federal Government? And a follow up: Do you have any recommendations to improve this already successful program?

SHEILA JACKSON LEE
18th District, Texas

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Statement by Congresswoman Jackson Lee
Hearing on the Partnership for a New Generation of Vehicles (PNGV)
July 30, 1996

Sheila Jackson Lee

When President Clinton was elected four years ago, he made the environment one of his important issues and the inauguration of the PNGV program demonstrated his commitment to helping industry find clearer and better ways of doing business. In fact this program is important enough to earn direct participation from the Vice President's Office. While I have hopes that a cleaner more efficient car will indeed result from this cooperative effort, I am glad that we are having this hearing, for it is time that this committee exercise its oversight responsibility and address the status of the program.

With twelve Federal Departments, Agencies and government entities partnered with Ford, Chrysler and General

Motors, PNGV is a complex and large effort involving competing participants and difficult technical goals. I for one am interested in hearing a status report and learning how well the government has managed the program, what accomplishments have been made, how this effort related to the efforts of the individual companies and what the near and long term outlook for the program efforts.

PNGV is a program with ambitious goals and initiated with much promise. However, many times, well intentioned programs have gone off course, returning very little to the taxpayers for their investment. I hope that is not the case with PNGV but if there are problems, it is my sincere desire that the problems be fixed, the course corrected and the undertaking set straight; for while I believe we owe our grandchildren a small federal government debt, we also owe them a livable environment and world.

Appendix II

RESPONSE TO QUESTIONS FOLLOWING THE HEARING ON

Partnership for a New Generation of Vehicles (PNGV):
Assessment of Program Goals, Activities, and Priorities

Tuesday, July 30, 1996

THE HONORABLE LIONEL S. JOHNS
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

(1) Although Goals 1 and 2 contribute to Goal 3 [of the PNGV initiative], they address the more short-term issues facing the auto industry and perhaps involve competitive research/development areas.

- **(a) How were these goals (1-3) initially developed?**
- **(b) What were the rationale for these goals and do they need to be modified?**
- **(c) Is there a need for continued involvement of Federal government in Goals 1 and 2 efforts, and if so, why?**

(1) (a) The goals were initially developed through discussions between the government and the Big 3 car companies to arrive at a set of goals that met both the government's policy needs and the industry's research objectives.

(b) As previously stated, the majority of the government's funding for the project will be directed to Goal 3. However, from the government's perspective, work on each of the three goals was and is important to reach energy security and environmental, as well as competitiveness, goals. Research into certain manufacturing issues (Goal 1) will be critical to reaching the long-term efficiencies set out in Goal 3. For example, development of improved, faster and cheaper manufacturing processes will be essential to getting the cost of lighter weight materials down low enough so that they can be used in commercial light duty ground vehicles.

Similarly, use of new technologies as they become available in vehicles going to market in the short term (Goal 2) is critical to meeting the government's energy efficiency goals generally, and the long-range Goal 3 specifically. It is in the government's and the nation's interest to have the car companies agree to bring more efficient technologies to market immediately upon availability so that short term fuel savings can begin immediately. It is also good research practice to get these technologies on the road rather than keeping them in the lab for ten years, waiting for the Goal 3 vehicle.

(c) For the reasons set out above, there clearly is a need for continued government involvement in certain projects that relate more to Goals 1 and 2 than to Goal 3. Certain of those projects will increase the likelihood that Goal 3 is met, and will address nearer-term policy issues as well. As with all research projects, the extent of the government involvement, or the nature of the cost sharing with industry, will be decided on a case-by-case basis. Clearly there may be some projects under Goals 1 and 2 for which industry should bear most or all of the cost.

(2) According to the NRC review and discussions by the PNGV technical working group, cost reduction and safety are often listed as highly critical technical barriers needing further research. However, while these items may require research, often they involve manufacturing and engineering issues that are directly related to the competitiveness of the performer. Do you have, or can you propose, criteria for determining which areas of such research really warrant government funding?

(2) The cost reduction and safety issues that are identified by the technical teams as critical technical challenges are not minor changes to today's cars and manufacturing systems. Rather, they are issues associated with the production of Goal 3 vehicles that are tied directly to the use of new technologies such as lightweight materials and breakthroughs in energy storage and energy conversion.

Research in cost reduction is an area in which some of the most important research advances are necessary. Similarly, the challenge of producing strong, light-weight, easily manufactured materials is central to the PNGV effort. For example, material and fabrication prices that may be acceptable for manufacturing aircraft are not acceptable in automobiles. Research advances in the production of polymer materials or aluminum forming, involving basic issues in materials science, are critical. Thus, at this stage of the project, research is long-term and high risk, and is not directly related to the companies' competitiveness in any current markets.

As stated above, the proper level of government funding must be decided on a project-by-project basis in light of the specific nature of the project and the status of the overall research effort and its needs. I do not believe that generic criteria can or should be formulated that would attempt to answer this question for all projects. A long-term, high risk effort such as we have undertaken is simply too fluid and unpredictable to be held to rigid general requirements for government funding.

In addition, the fact that a research project may relate to the competitiveness of the industry should not necessarily preclude government involvement in the research, and the NRC peer review report did not suggest that it should. The fact that research undertaken to address environmental or energy security issues also may ultimately render our domestic industry more competitive in world markets and thereby increase the availability of U.S. jobs, should be considered a positive, not a negative element.

(3) Why is the pre-competitive research funding via contracts and CRADAs with each of the Big Three auto companies separately, instead of funding USCAR as a consortium?

(3) USCAR can and does receive government funding through the PNGV project; for example, in the past NASA funding for PNGV's systems analysis work has been handled by USCAR. Some work is also funded directly through specific technology partnerships under the USCAR umbrella, such as the U.S. Advanced Batter Consortium. Many of DOE's cost-shared cooperative agreements predate PNGV and, consequently, are with the individual companies. In general, DOE funding for PNGV is handled under a variety of different mechanisms, with the choice based on what is best suited to meet the partnership's needs. PNGV's technical team structure provides a forum for sharing of information and collaboration among the car companies, and even work that was originally awarded on a company-by-company basis, such as hybrid vehicle platform development, is now being closely coordinated, with all of the companies sharing technical information.

(4) Please respond to the review comments by the PNGV Standing Committee of NRC, which aside from the specific technical recommendations, point out the following shortcomings of the PNGV program:

- **(a) Lack of a single technical program director for the PNGV government management or the USCAR.**
- **(b) Lack of an empowered management structure at DOE and DOC to affect the array of Federally funded projects.**
- **(c) The need for more support and involvement in the PNGV research program by NASA, DOD, and DOT (specifically, lack of attention to safety issues arising from drastic changes in material and structure required for the PNGV vehicles).**
- **(d) The need for analysis of current and post-PNGV technologies, overall system analysis, a well-defined and detailed program plan and adequate resource allocation.**

(4) (a) We have made management changes since the NRC report. The structure includes the Chair of the government technical task force, who coordinates participating agencies' and industry technical efforts; and a newly-created position of Chair of the government technical council, who is responsible for tracking the overall technical progress by overseeing the work of the government technical managers in each research area. However, neither of these employees are authorized to direct other agencies' missions. We simply disagree with the NRC that such authority is

necessary or appropriate. To do that would require changes in the extent of each agency's statutory authority as well as interference with Congressional Committee jurisdiction. We do not believe that such a major overhaul of established structures is necessary to accomplish the work of the project. Indeed, we believe that after much hard work and creative management structure we have reached a point that we can accomplish the needs of the program collegially rather than in an authoritarian way.

(b) Since the NRC report we have added a Chief Financial Officer to the management team, who is an employee of the Office of Management and Budget and authorized by the OMB Director to track and if necessary begin the process of redirected funds in the entire budget related to PNGV. This person does not have the unilateral authority to redirect funds, for the reasons stated above, but can track the total budget picture unrestricted by agency jurisdiction and can work with OMB and agency managers to make necessary changes.

(c) See Mr. Johns's responses to pre-hearing questions. DOT and NASA requested funds to work these issues, and both were zeroed out by Congress in the last fiscal year. This does not reflect a lack of interest on the agencies' parts. DOT is optimistic that the requested funding will be restored in 1997 to allow for its involvement in crashworthiness work. In the interim, the DOE's Office of Defense Programs and Energy Research currently support a CRADA between five DOE labs and the USCAR consortium on supercomputing to develop analytic tools to predict the energy absorption and collapse mechanisms for lightweight composite structures.

In addition, DOT/NHTSA has had underway a project at DOE's Lawrence Livermore National Lab to develop new models for the DYNA-3D crash modeling code. While this project predated PNGV, we expect the results to be useful to the project.

Finally, DOE's Office of Transportation Technologies 1996 budget request included $550,000 to begin collaborative efforts with DOT to evaluate crash behavior of vehicles structures fabricated form lightweight materials. Congress did not fund this work.

(d) As the NRC Chair testified, overall systems analysis work has been underway for over a year. Prior to that time, each car company has its own analyses underway, so no time was lost to the project. That project was funded by NASA, and Congress has not appropriated additional NASA funds to continue this project. However, we are working to find funding sources for the project from other agencies, and are confident that we will do so in time to avoid any lapse in the work.

(5) How would you respond to a Congressional requirement to establish the review process, such as the existing NRC review, as a permanent part of the PNGV program?

(5) An annual peer review has always been a key element of the PNGV project, and the original declaration of intent, issued in 1993, made clear that annual peer review would be performed throughout the project. Thus, both parties are committed in writing to this, and there is no need for Congressional mandates. However, such a mandate would not be in any way inconsistent with the project's plans for such review. Congressional support of this review in the form of appropriated funds to cover the cost would, however, be most appreciated.

(6) In the written testimonies and other PNGV publications, the role of DOD is described as important within the PNGV program, yet, at least for the last two years, the Administration budget request for hybrid electric vehicle programs at DARPA (formerly ARPA) has been zero, and each time Congress allocates additional funding. What is the rationale?

(6) Significant work underway at DARPA on advanced ground vehicles that is relevant to the PNGV program, such as the Combat Hybrid Power Program, is part of the Administration's budget request. The question apparently refers to the Electric and Hybrid Electric Vehicle Technology Program, a program funding regional research consortia, which since its inception, has been supported by congressionally-initiated appropriations.

(7) How do you respond to the criticism raised in the NRC's review of the program management? Please specifically respond to the suggestions by Dr. Hirsch, of the NRC Standing Committee, and Professor Sterling that DOE should be the lead agency in the PNGV program.

(7) The selection of DOC to be the coordinating agency for the project was made in large part because DOC was created, in part, to work with industry to ensure its competitiveness. PNGV is a unique industry partnership that requires an unprecedented management structure. The government entered into it to address policy issues related to the missions of several agencies, but only DOC has as its primary mission work with industry.

We believe it is too simplistic to suggest that the agency that contributes the most money to the partnership should, by definition, be the one to manage it. Three general points should be noted. First, DOE has not expressed dissatisfaction with the current arrangement nor any belief that it interferes with achievement of its mission or the goals of the project. In addition, the DOC's role is not to usurp the independent authority of any other agency, but to coordinate the work among the agencies and with industry, suggest changes where necessary, and find a collegial way to implement those changes. It is in a position to act as an honest broker and to ensure that the multi-dimensional objectives of the project are approached as an integrated engineering challenge consistent with, but not limited by, other agencies' mission statements. Finally, DOE employees play significant roles in both the technical and policy management structure. A DOE employee was brought on to address the need for additional technical oversight identified by the peer review, and the Assistant Secretary of Energy is a member of the policy steering committee for the project.

In addition, a change in the lead coordinating agency at this point could create, rather than solve, management problems. As stated above, only DOC has as its mission work with industry. Given that mission it is in the best position to serve as a neutral broker between the competing agency contributions and missions, in part precisely because it does not have a major financial stake in which research projects get chosen. Finally, while DOE currently contributes more than any other agency, several other agencies spend significant amounts of their research dollars on relevant work and may not react well to the idea of management structure based on financial contributions.

(8) Why does not the government attach a higher priority to developing an H2 infrastructure given the fuel cell potential?

(8) See Chapman Response #11; Gross Response #9.

(9) We understand that MAN, a major European bus manufacturer, BMW, and Daimler-Benz, as well as Mazda, in Japan, are demonstrating conventional hydrogen-burning internal combustion (IC) engines.

- **(a) Is a hydrogen-fueled IC engine being considered by PNGV and if not, why?**
- **(b) Are hydrogen infrastructure issues easier to solve in Europe or Japan than in the U.S.?**
- **(c) Has there been any study to determine the feasibility of developing such an infrastructure?**

(9) See Chapman Response #12(a); Gross Response #10(a).

(10) You stated in your testimony that the Japanese and Europeans are devoting much more resources to their PNGV-like programs. What proportions of their programs are focused on infrastructure issues and how do they address the pre-competitive research funding compared to the U.S. approach?

(10) While we have general information about the gross totals being spent, and we speculate that more is being spent that we are specifically aware of, we do not have enough detailed information to determine what is being spent on infrastructure issues by our foreign competitors.

(11) In your response to pre-hearing questions, you discuss agency missions and their jurisdiction as a reason for not having a single Chief Technical Officer for the government PNGV program. Why does the agency with the least technical and financial stake (namely DOC) have the nominal control of the overall government management?

(11) See Response # 7 above.

(12) In your response to pre-hearing questions, you mentioned recent management reorganizations and designating a Technical Director for the PNGV. Can you elaborate on this reorganization and describe how it resolves the type of issues raised in this question and those that concerned the NRC review committee?

(12) See Response #4(a) above; Chapman Response.

PNGV
PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

September 16, 1996

Responses to
Questions following the hearing on
PARTNERSHIP FOR A NEW GENERATION OF VEHICLES (PNGV):

HELD ON
1:00 p.m. - 400 p.m
Tuesday, July 30, 1996
2318 Ray House Office Building

BY THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Questions Addressed to Mr. Robert M. Chapman
Chairman, Government PNGV Technical Task Force

1 *Will PNGV be able to meet all the technical requirements needed to properly select the most promising technologies by 1997?*

A. We believe so.

Although we have not completely defined the technology selection procedure, from the government's standpoint we may say the following The "selection" of a technology in a given area (e.g., energy storage) should lead to increased priority for funding of problem-solving in that area. However, this will not necessarily mean the termination of government support for other, competing technologies; it could merely indicate a lower level of funding is appropriate (e g If flywheels are selected, the funding for flywheel research would need to be increased In contrast, research on the other two competing technologies--high-power batteries and ultra capacitors--might be continued-- albeit at a lower level) In the latter case the research may be oriented toward a future vehicle application beyond the horizon of PNGV.

2. *Can you comment on the level of progress of Goals 1 and 2 of the PNGV initiative?*

A. The report, "PNGV Technology Accomplishments" which was furnished to the Subcommittee, contains a significant number of projects that bear on Goals 1 and 2. Of the 65 accomplishments listed in the book, roughly 26 relate to Goal 1 and 11 to Goal 2 (some relate to both Goals) In as much as Goal 3 is longer range, its related research accomplishments are not expected to materialize until later

a) *How much of the funds have been devoted to these two goals?*

The attached table lists Goal 1, 2 and 3 funding

3 *Is there a need for continued involvement of federal government in Goals 1 and 2 efforts, and if so, why?*

A. As we have proceeded with the PNGV technical effort, we have shifted the emphasis on Goal 1 (Manufacturing competitiveness) from a global orientation to one more specifically focused on the manufacturing impediments anticipated with the new technology components to be incorporated in PNGV vehicle systems. As a consequence, Goal 3 is being supported as well. These projects are certainly high risk in that they will involve the manufacture of items never before attempted at high production rates. Therefore, there is a clear need for continued government involvement to help improve the manufacturing competitiveness of our industries

Our Goal 2 philosophy is that, as PNGV research proceeds and developments are found able to be applied to conventional vehicles, they will be implemented Industry has pledged to apply commercially viable technologies resulting from this research where it might be expected to increase vehicle fuel efficiency significantly and reduce emissions There are projects under Goal 2 (and Goal 1 as well) for which industry will bear most of the cost.

4. *According to the NRC review and discussions by the PNGV technical working group, cost reduction and safety are often listed as highly critical barriers needing further "research." However, while these items may require research, often they involve manufacturing and engineering issues that are directly related to the competitiveness of the performer. Do you have, or can you propose, criteria for determining which areas of such research really warrant government funding?*

The criteria should be the same as for all PNGV research projects supported by the government They must be high-risk, long-range technologies that are critical to the goals of the program Research that goes beyond the generic, collaborative, pre-competitive category should not be supported by the federal government

One should keep in mind, however, that the cost-reduction and safety issues that the NRC and technical working groups are referring to are not for technologies currently in mass production, but for technologies and material that will need to be mass produced in the future to achieve Goal 3

5. *Why are the Big Three auto companies funded separately for pre-competitive research via contracts and CRADAs instead of funding USCAR as a consortium?*

USCAR is a legal entity and may receive government funding. The method of funding PNGV research varies according to a judgement on what contractual arrangement best meets the partnership's needs Many of the cost-shared cooperative agreements and CRADAs predate

PNGV and, consequently, are with individual companies In general, a variety of different funding mechanisms have been utilized In one important recent example, the NASA funding for support of systems analysis was channeled to USCAR PNGV's technical team structure provides the forum for sharing information and for pre-competitive collaboration among the individual car companies.

6 *How do you respond to the review comments by the PNGV Standing Committee of NRC, which aside from the specific technical recommendations, point out the following shortcomings of the PNGV program:*

a) *Lack of a single technical director for the PNGV government management or USCAR.*

A. The auto industry has explained repeatedly their reasoning for their management structure. I refer you to Mr. Mull's response.

With regard to the government side of the partnership there is -- and has been right along -- a single technical program director: me The issue the NRC has fastened on is that of the government program management directing other agencies' technical efforts in support of PNGV There are sensitive issues raised when one federal department interjects itself into programmatic decision-making in other agencies Because of the realities of agencies' missions, Congressional authorizations, appropriations and similar constraints, the process of gaining support for PNGV objectives must, in most cases, be pursued by leadership through education and persuasion. This process has been facilitated recently by the creation of a Chief Financial Officer in the Office of Management and Budget (See also answer to question number 4b posed to Dr L.S. Johns)

b) *Lack of an empowered management structure at DoE and DoC to affect the array of federally funded projects.*

A. Early this year the Department of Energy restructured its organization to place all PNGV-related activity in its Energy Efficiency division under one manager. He now has the ability, within Congressional appropriations guidelines, to shift funds. The management structure of DoE relative to PNGV, therefore, may be considered empowered.

The DoC, on the other hand, does not have access to any central source of funds that might be dispensed to other agencies to support PNGV projects.

c) *The need for more support and involvement in the PNGV research program by NASA, DoD and DoT (specifically lack of attention to safety issues arising from drastic changes in material and structure required for the PNGV vehicles).*

A. NASA in the past, has funded the systems analysis work and NASA personnel continue to participate in PNGV technical activities In FY96 Congress deleted all funding identified as PNGV-specific based on their belief that it was not a NASA priority. DoD is collaborating in the power electronics, flywheels, manufacturing and materials areas DoT requested funds in FY96 to support research on safety issues. Their request was denied by

Congress as being premature However, we believe their request will be at least partially supported by Congress in FY97 It is our expectation that there will be increased support for PNGV from these agencies in the future.

d) *The need for analysis of current and post-PNGV technologies, overall systems analysis, as well-defined and detailed program plan and adequate resource allocation.*

A. The need have already been addressed. Analysis of current and post-PNGV technologies is on-going; the overall systems analysis model has been developed and validated. A revision of the program plan was prepared in November 1995 Copies of the revised plan were furnished to the subcommittee before the hearing.

7) *How would you respond to a Congressional requirement to establish the review process, such as the existing NRC review, as a* *permanent part* *of the PNGV program?*

A. The NRC Peer Review is mandated in the Declaration of intent, the basic agreement between the government and industry The Peer Review and the continuing interaction of the Chairman and committee members have been a very beneficial component of the PNGV program. We have had persistent difficulty obtaining funding for the Peer Review, especially at the level the NRC recommends The DoC has been the main source of funding with other agencies contributing.

8) In *the written testimonies and other PNGV publications, the role of DoD is described as important within the PNGV program, yet, at least for the last two years, the Administration budget request for hybrid electric vehicle programs at DARPA (formerly ARPA) has been zero, and each time Congress allocates additional funding. What is the rationale?*

A. Much of the works underway at DARPA on advanced ground vehicles is relevant to PNGV and is part of the Administration's budget request The hybrid electric vehicle consortium program predated PNGV. Since its inception, it has been supported by congressionally-initiated appropriations.

9) *The PNGV program is more than three years old, yet an important component, namely an overall system analysis (also emphasized by the NRC panel) has not been accomplished.*

It was not accomplished at the time of the last Peer Review in August 1995. However, at this point models have been developed and validated for an overall systems analysis along with supporting models for key technologies. Continued effort will be necessary to refine the models in light of developments in the research process, but that was expected.

a) *How can you have any certainty in your success given the lack of such capability?*

A. We have successfully validated our systems analysis models.

b) *Would it not be more desirable to perform an overall system analysis that can be used as a "design/system performance evaluation?" Why?*

This is what we have done and will continue to refine. (There appears to be a difference between what we define as systems analysis and what the subcommittee understands it to be This may best be resolved by a briefing on this topic or a specific report by the NRC after their next review.)

10) What *are the most critical technical barriers, aside from cost reduction and hydrogen (H_2) infrastructure issues, for the use of fuel cells in automobiles?*

A. Those two are challenge enough! We currently are operating a stack at the 10kw level. In order to be a credible candidate, a fuel cell should be able to demonstrate reliable performance at the 60-80kw level. Problems not presently imagined will most likely appear when a full-scale fuel cell is subjected to real world operating conditions.

11) *Why does the government not attach a higher priority to developing an H_2 infrastructure given the fuel cell potential?*

A. Under the present schedule, with the PNGV production prototype fielded in 2003, the earliest model year introduction would be about 2006 -- ten years from now. Begging the question of whether the government should be developing such an infrastructure, PNGV research on fuel cells has not reached the stage where we may with certainty say what kind of infrastructure would be needed. This could range from H_2 gas pipelines to reforming stations with cryogenic or high pressure storage The investments required could be tremendous and a wrong guess at this stage would be very expensive.

12) *We understand that MAN, a major European has manufacturer, BMW and Daimler-Benz, as well as Mazda, in Japan, are demonstrating conventional hydrogen-burning internal combustion (IC) engines.*

a) *Is a hydrogen-fueled IC engine being considered by PNGV and if not, why?*

A. Yes. There are compelling inherent advantages to hydrogen as a fuel that cannot be ignored. The EPA's Ann Arbor laboratory has the lead for investigating candidate fuels for I.C engines. Additionally, several of the Department of Energy's national laboratories are engaged in such research. The DICI (engine) Technical Team will select the appropriate fuel based on optimum performance of the engine, environment consideration and necessary infrastructure.

b) *Are hydrogen infrastructure issues easier to solve in Europe or Japan than in the U.S.? Has there been any study to determine the feasibility of developing such as infrastructure?*

A. We have taken an initial look at infrastructure issues. That effort is planned to continue with increasing depth as the definition of the preferred PNGV fuel form becomes clearer. If the Europeans or the Japanese have relevant infrastructure, we will certainly wish to learn as much about it as possible. (See T. Gross' response for elaboration)

We also must consider that H2 is expensive to produce. In countries where gasoline costs $3 to $4 per gallon, hydrogen may look competitive as a fuel long before it does in the U.S

13) *Composites are widely used in aerospace, boats and some automobiles. A great deal of PNGV-relevant research, particularly funded by ATP (about $136 million for FY95-97), involves composites materials and manufacturing techniques. Many of the projects address cost reduction and high-volume manufacturing development.*

a) *What is the role of the federal government in such projects?*

A. The composites currently used in boats and cars are generally not used for primary load-bearing components, other than hulls, which handle distributed loads and are hand-built. Aerospace composites are suitable for high-load applications, but they cost typically about 10 times more than they would have to for mass production There are not affordable composites available that can be used to make automobile suspension or steering components, for instance.

The Advanced Technology Program challenges private-sector firms to achieve major technological progress of long-term national significance in the face of dynamic market conditions. In the private-sector the focus is often on short-term, lower risk technical problems leading to only incremental advances. High risk, fragmentation of technical effort, diffuse benefits, and lack of patient R&D funding can seriously retard industry progress. NIST/ATP participation can catalyze industrial technology development efforts and enhance private funding to get the job done more quickly

The ATP Manufacturing Composites Structures program represents such an effort to catalyze multiple companies and multiple industries in action. The program was initiated in 1995 following submissions of whitepapers from a broad cross-section of the composites industry, and a series of meetings to define specific industry needs. The U S. industry consensus was that commercial, non-military, non-recreational applications of polymer matrix composites were severely limited by high manufactured part cost, the complexity of design inherent with this class of materials, and the inherent risk in the introduction of new materials It was the strong view of industry that a partnership with the ATP was needed to achieve the critical mass of resources and coordinated effort across the supply chain required for widespread application for composites It was also shown that only a small percentage of federal R&D funding was directed to manufacturing of this now intermediate class of composites positioned between low-end applications such as shower enclosures and sailboats, and high-performance aerospace applications such as military aircraft. Most importantly, industry indicated that the technical barriers to commercially cost-competitive manufacturing in industries such as automobile manufacturing were significant and required sustained research much higher in risk than that currently being supported by the materials

PNGV
PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

September 16, 1996

Responses to
Questions following the hearing on
PARTNERSHIP FOR A NEW GENERATION OF VEHICLES (PNGV):

HELD ON
1 00 p m - 400 p m.
Tuesday, July 30, 1996
2318 Ray House Office Building

BY THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Note. The answers to these questions were developed in close collaboration with USCAR Their response is presented here also with some additional comments as appropriate.

Questions posed by the Honorable Bill Baker.

Q1) *Is it your understanding that the PNGV program is currently open and accessible to interested small businesses?*

We have heard some concern expressed by small businesses who state that they have attempted to become involved in the PNGV program, but faced many hurdles in doing so.

A. We have established mechanisms in several agencies of the government and targeted programs for small suppliers and universities. There are some 400 suppliers (universities, laboratories, and established, as well as non-traditional, companies) involved with PNGV We are expanding the involvement of second and third tier and non-technical suppliers. For these constituents, there are numerous outreach efforts, urging and easing participation. Examples include:

- Inventions Needed for PNGV is an important outreach publication used to solicit ideas and to inform interested third parties on how to become involved. It is also accessible on the Internet.
- We have held "outreach" workshops this year on the following topics: CIDIs, aluminum, chassis materials, fuel cells and manufacturing, electronics and electrochemical energy storage.
- Symposia have been held in Washington, D.C. to bring together the nation's experts in such areas as fuel cells, advanced materials, electrical and electronics, and energy storage.

- The FutureCar program involves universities and numerous suppliers
- The government's Small Business Innovative Research (SBIR) program and Energy Related Inventions Program (ERIP) enable small suppliers to become involved in PNGV related research
- NSF welcomes university proposals on PNGV topics subject, of course, to normal peer review.

Innovative concepts are protected by normal legal processes as in any research collaboration

Q2. *How much of an emphasis is put on small business contributing new technologies and innovation to the program*

A. At present, we have about 400 organizations involved in PNGV, many of which offer new enabling technologies. Several small non-traditional firms are also participating. PNGV also includes a process for suppliers or private entrepreneurs to obtain information about the program and to submit their ideas. A recently published document entitled Inventions Needed for PNGV is being used to solicit ideas and to inform interested third parties on how to become involved.

Q3. *How much of an emphasis is placed on small businesses filling a needed technical void under the PNGV's prevailing design plans?*

A. The program is seeking breakthrough technology irrespective of source or geographic location. While the Partnership is sensitive to the point that it needs to take special care to evaluate technologies from small entrepreneurial firms, its emphasis must remain on securing the best available technologies.

Q4. What mechanisms exist for new innovative technologies proposed by small businesses to be pursued if they are not being considered by the Big Three?

A. The government has several existing mechanisms that can help individuals and small businesses. Examples are the Small Business Innovative Research (SBIR) programs of every participating agency and DoE-funded, NIST-executed Energy Relation Inventions Program (ERIP). Beyond these programs, agencies are supporting work with smaller companies, without any direct participation by any of the USCAR partners. Examples include the seven ARPA regional consortia working on hybrid and electric vehicles and DoE CRADAs with various third parties

Ultimately, though, the reality is that a small business will have to convince at least one auto maker to use its innovative technology, or it will not reach the mass market.

Q5. *Would it be a standard business practice to sign non-disclosure agreements with a small businessman who come to the PNGV program in order to determine the worth to the program of a new technology he or she wanted to advance? If not why not?*

A. The government receives many suggestions and ideas from small businesses on ways to use our energy resources better. In general, we prefer not to sign non-disclosure agreements in order to determine the worth of a new technology to the program. Instead, in the recent PNGV report, Inventions Needed for PNGV, the different ways small businesses and individual inventors may participate in PNGV are identified. For example, to evaluate new technologies, DoE and the National Institute of Standards and Technology (NIST), frequently rely on the Energy-Related Inventions Program (ERIP). This program was established by Congress to provide small businesses and individual inventors a simple mechanism to evaluate the feasibility of a new technology, and possibly to provide financial support for the development of energy-related concepts and inventions. NIST provides, at no cost or obligation, an evaluation of concepts and inventions to determine their technical feasibility, marketability, and potential for significant energy conservation or improvements in the supply of energy. The NIST keeps all invention disclosures under strict control. Promising inventions are forwarded to DoE for possible financial support

Q5a. *Is this a standard procedure that the government follows in its negotiations?*

A. The report Inventions Needed for PNGV, describes a variety of mechanisms whereby DoE can join with small businesses and individual inventors to participate in PNGV. These programs include, for example, the Small Business Innovative Research Program, Energy-Related Inventions Program, and the Small Business Technology Transfer Program. Each program has standard procedures for protecting confidential information. Initially, the Partnership would prefer to evaluate new technologies without the bureaucratic delays inherent in non-disclosure agreements. Small businesses are encouraged to protect information through patents and other traditional mechanisms consistent with established business practices. If a technology appears to have promise, it is typically in the best interest of both the supplier and the Partnership to enter into non-disclosure agreements.

Questions posed by the Honorable Jackson Lee

Q1. *The structure and management of the program have been called into question by some people. Can you give me recommendations as to how the program could be restructured on the government or industry side to bring about better or more efficient management?*

A. The management structure of PNGV was agreed upon by the auto companies and their partners in the Federal agencies. At the time everyone recognized the realities of agencies managing within existing program budgets. The complications inherent in large competing companies working together on pre-competitive research was also recognized. We all understand now that this management structure is somewhat tedious in that it must rely on consensus building rather than command and control. But just as no Federal agency or Congressional committee will cede control of its budget to another, it is even less appropriate for a corporation to cede control of future products to a competitor's project manager. We have continued to improve efficiency within the present structure by sharing pre-competitive technology and combining industry/government research programs whenever possible. The shared-responsibility management system we are using is familiar to anyone who has worked with risk-sharing joint ventures. While cumbersome at times, this consensus style of operation leads to frank dialog about issues and potential solutions and produces high-quality decisions.

Q2. *When do you see the technologies being developed under the PNGV program coming into wide use in the production of automobiles?*

A. The industry has committed to offer new technologies developed in PNGV on conventional vehicles as soon they become commercially viable. This process has already begun with the introduction of both composite and aluminum parts (such as hoods and trunk lids) to replace conventional steel applications for weight reduction. As the technical development process continues, more and more applications are expected to benefit all classes of vehicles leading to more efficient vehicle fleets that offer increased payload or increased fuel efficiency options to the public.

Q3. *Can you tell me what the returns are that we can expect from the PNGV program in terms of reduced oil usage, new car exports and environmental benefits?*

A. PNGV is a research program with very ambitious goals. The positive contributions of the program will be directly related to the degree we achieve our objectives and the public accepts this new class of highly sophisticated vehicles. It is difficult to identify specific timetables and deliverables for PNGV benefits. However, we believe development of these technologies will have widespread societal benefits such as the preservation of high-paying jobs and contribute to air quality, energy security, and improved industrial competitiveness.

The returns we may expect from PNGV depend greatly on a number of factors, including the degree to which we achieve our objectives, the commercial acceptance of the vehicles (market penetration), the price and availability of oil, and the future imposition of additional state and federal regulations. The commercialization of technologies now under development in support of PNGV is projected to produce savings in oil of up to one million barrels per day by the year 2020. This would represent an annual savings in energy cost of around ten billion dollars (1994 dollars). Along with these energy savings, there would be a concomitant reduction in annual carbon emission of approximately twenty-five million tons.

Question posed by the Honorable Zach Wamp

Q. Does use of lightweight material in building [automobiles] compromise [their] safety?

A. The PNGV goal is to achieve up to three times improvement in fuel efficiency without compromising customer acceptability of the product, including affordability and safety. The specifics of our technical strategy include up to 40% weight savings for the total vehicle. Our objective is to achieve the PNGV technical targets, including the weight savings, without compromising safety, performance or other customer expectations and needs.

This is a significant challenge. The connection between occupant safety and vehicle weight and size has been thoroughly examined over the years and is well understood for the current materials and designs used in cars and light trucks. A number of studies have been done by government and private sector organizations that have clearly demonstrated that reducing either vehicle size or weight will reduce occupant safety. This safety impact has been a major concern of the auto companies when responding to regulations such as higher fuel economy standards for vehicles, which may lead to reduction in vehicle size and/or mass. We therefore wish to see Congress approve the funding DoT has requested for PNGV research in the National Highway Safety and Traffic Administration (NHTSA)

The PNGV program expects to avoid one of these problems by not undertaking any significant downsizing in the vehicles. Maintaining vehicle size will maintain the crush space of existing vehicles and thus will not reduce the space in the PNGV vehicles in which the energy of the crash must be managed

Just as important as size, however, is the mass (or weight) of the vehicle. In most accident situations, the occupants of the vehicles involved are better protected when their vehicles have more mass. According to the basic laws of physics heavier vehicles have an advantage in deforming or displacing obstacles such as trees, poles and fences. This allows these vehicles valuable additional space to decelerate the vehicle and its occupants. Statistical evidence shows that these safety advantages afforded to occupants of heavier vehicles more than outweigh any disadvantages, such as increased risk to pedestrians or bicyclists. Thus, PNGV's goal of reducing weight by 40% without adversely affecting safety is a substantial task

New steel, aluminum, and composite materials will be used to accomplish the weight savings. A key criterion in material selection and design will be the properties that these materials display in vehicles. Aluminum and composites have shown the potential to be superior energy absorbers compared with current materials.

Vehicle structural designs and enhanced occupant restraint systems are expected to be the primary tools for achieving today's equivalent crash protection performance with lighter weight materials

Automotive safety is an important component of PNGV. If we meet the goal of 80 miles per gallon, but cannot meet the safety standards Americans expect, then we have failed. The goals of PNGV are very clear: the vehicles must meet all applicable Federal Motor vehicles' Safety Standards. PNGV-related safety issues are currently being studied at several federal laboratories. The unique expertise of ORNL in the field of lightweight materials is playing a critical role in helping DoE, and our industry partners, assure the safety of America's cars of the future. For example, ORNL is a partner in a cooperative research and development agreement with the automakers and four other DoE national laboratories in developing analytic tools to predict the energy absorption and collapse mechanisms of composite structures for crash and energy management applications. We hope, additionally, that in FY97 NHTSA will also be active in this area.

In summary, reducing mass (weight) generally involves reducing vehicle safety. We believe that maintaining size and crush space while incorporating the new advanced materials and safety technologies that are emerging from PNGV research will allow PNGV to increase fuel efficiency by up to three times without sacrificing safety.

Questions Following the Hearing on

Partnership for a New Generation of Vehicles (PNGV):
Assessment of Program Goals, Activities and Priorities

Submitted by the
Subcommittee on Energy and Environment
Committee on Science
U.S. House of Representatives
to
Dr. Joseph Bordogna
Assistant Director for Engineering
National Science Foundation

1) Although Goals 1 and 2 contribute to Goal 3 [of the PNGV initiative], they address the more short-term issues facing the auto industry and perhaps involve competitive research/development areas.

    a) How were these goals (1-3) initially developed?

ANSWER: The PNGV goals were defined and shaped based on a series of studies and partnerships developed among the agencies. With the appointment of Science Advisor Dr. Jack Gibbons, an interagency subcommittee was formed within the Federal Coordinating Council on Science, Engineering and Technology (FCCSET) Advanced Manufacturing Technology (AMT) initiative to study research and development issues relevant to automotive technologies. This subcommittee worked for several months. The results were presented to representatives of the automotive industry for their consideration. After considerable discussion agreement was reached on the common goals that were subsequently announced by President Clinton on September 29, 1993. When the National Science and Technology Council (NSTC) was created, the activities of the FCCSET AMT subcommittee were subsumed into the newly-formed PNGV effort, and became part of the activities of the NSTC Committee on Civilian Industrial Technology (now the Committee on Technological Innovation).

    b) What were the rationale for these goals and do they need to be modified?

ANSWER: The rationale for a strong emphasis on a new generation of vehicles relates to the investment strategy employed for the entire federal R&D budget: to create and sustain an infrastructure usable by all to create new knowledge and enable U. S. leadership in the automotive industry. The focus of these goals is on enabling a manufacturing infrastructure which industry generally can draw upon, and to stretch beyond what is possible with current technology.

Goal 1, to improve competitiveness in manufacturing, is not confined to short-term advances, although these are a major part of it. As an example of longer-term work, NSF and DARPA are jointly supporting an initiative this year entitled "Experiments in Distributed Design and Fabrication and Rapid Prototyping Using Agile Networking." This effort is aimed at enabling linkages between industry and manufacturing and computer science research communities to develop new methodologies and standards, based on rigorous research results, that will make distributed manufacturing possible.

2) According to the NRC review and discussions by the PNGV technical working group, cost reduction and safety are often listed as highly critical technical barriers needing further "research". However, while these items may require research, often they involve manufacturing and engineering issues that are directly related to the competitiveness of the performer. Do you have, or can you propose, criteria for determining which areas of such research really warrant government funding?

ANSWER: From NSF's point of view, new knowledge can be used in two ways: (1) to improve productivity, thus enabling cost reduction of products and processes that already exist; and (2) as the basis for innovation to create new products and processes, many of which could lead to improved safety. The greatest advances in cost reduction and safety are likely to come from radically new approaches to materials processing and manufacturing, rather than from incremental improvements in existing technologies. The role of federal R&D investments should be toward the speculative, high-risk/high-payoff ideas that are judged by technical experts to be fundamentally sound. Our fast-paced technological society depends on complex, ever-changing products, processes and systems, but failure in design or manufacture can lead to large-scale harm. Safety is becoming more and more an important issue, but approaches to achieving it are also becoming more complex. There are now academic disciplines that dwell on the principles of safety, and engage in scholarly activities with the purpose of fundamentally improving the performance of all potentially harmful functions, materials, products, processes, systems, and behaviors in society.

3) How would you respond to a Congressional requirement to establish the review process, such as the existing NRC review, as a permanent part of the PNGV program?

ANSWER: NSF believes that review processes for special purposes are best carried out periodically as needed rather than within a permanent organizational structure. The PNGV investment is being made at a time in history where a national need exists. It is not intended to exist permanently. To review any such investment, the best people should be chosen who can make an objective and rigorous assessment within the context of the special purpose for which the investment was made.

4) Can you provide some historical background about the PNGV establishment and relevant discussions that may have dated back to the Bush Administration?

ANSWER: This background was provided as part of the answer to Question (1) above.

5) What is the significance of NSF's role in the PNGV program?

ANSWER: NSF believes its responsibility includes improving the connection between a long-term, fundamental search for new knowledge and its ultimate impact on industrial innovation. An integral part of NSF support for research is bringing the generalized concepts, knowledge and research techniques to the classroom and teaching laboratory to prepare students for successful careers contributing to the competitiveness and strength of U. S. industry. The PNGV program enables NSF-supported investigators to build stronger ties with those who will be the eventual beneficiaries of their research results as well as with the community of potential employers of their students.

6) Can you elaborate on the role of NSF in the PNGV program and in setting priorities?

ANSWER: NSF staff have begun to work informally with representatives of Chrysler, Ford, General Motors and other manufacturing companies to explain the merit review process, expose the university research community to PNGV-related technical issues, broker matches between industry experts and university researchers and encourage the participation of manufacturing industry experts in the review of research proposals. An NSF/DoE conference on "Basic Research Needs for Vehicles of the Future" was held in January, 1995, in partnership with major U. S. automobile manufacturers and their suppliers. 188 participants, from 34 different U.S. universities, 18 government agencies and 24 different companies in the automotive industry, worked together for three days to define the key research problems in the six most critical long-term research areas defined by the research staffs of Chrysler, Ford and GM. A follow-on conference in January, 1996, on "Basic Research Needs for Environmentally Responsive Technologies of the Future" identified industry-specific basic research opportunities in five industries, including the automotive industry. A third conference is being planned for late 1996 or early 1997 to focus on long-term engineering research issues relevant to PNGV.

The dialogue between the automotive industry and university researchers has already had positive effects. For example, NSF is negotiating a new five-year award for an Engineering Research Center (ERC) at the University of Michigan which can be considered an investment in PNGV research goals. This center was one of four new ERCs selected in competitive merit review from among more than 100 candidates in FY 1996. It brings Chrysler, Ford, GM, Caterpillar, General Dynamics, Boeing, United Technologies and 24 of their technology suppliers together with a team of university researchers to develop a new generation of low-cost machining systems that can be easily reconfigured to increase the flexibility of automotive, heavy vehicle and aircraft production. The ERC's research and education agenda directly and specifically addresses the long-term needs of three related industry sectors: Aerospace, Heavy Vehicles and

Automotive end users. The companies representing the industry supplier base that have joined this ERC effort are focused on Controls (7 members), Sensors (5), Machine Tool Builders (9) and Tooling (3). NSF also supports the Materials Research Science and Engineering Center (MRSEC) at Michigan State University, a partnership between Michigan State, Chrysler, Ford and GM established by NSF in 1994 to provide a focal point for fundamental research on materials and devices with high potential for application in vehicular sensing systems. Eleven NSF-supported Industry-University Cooperative Research Centers (I/UCRC) have attracted membership by the major U. S. automobile manufacturers because of their focus on research themes consistent with the long-term interests of these companies.

All these NSF projects were awarded through a competitive merit review process in which there was no targeting of technology areas by NSF. Nevertheless, the range of technical topics covered among the proposals NSF receives correlates well with PNGV emphasis areas. Leadership from the federal government, in partnership with industry, is having an impact on how the long-term research needs of U. S. industry are made known to the academic community. This in turn influences how academic researchers plan their own individually-conceived research and education goals.

7) If the projects are being initiated by the researchers without a direct solicitation, how would it be different if NSF were not part of the PNGV?

NSF's public involvement in the PNGV raises the profile of research issues that are linked to advances in automotive technologies. It stimulates academic researchers to envision and propose PNGV-related research to NSF. It also encourages potential collaborators in auto manufacturing companies to consider collaborating with academic researchers and educators.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q1. Will PNGV be able to meet all the technical requirements needed to properly select the most promising technologies by 1997?

A1. It is highly unlikely that by 1997, *all* technical requirements needed to select properly the most promising technologies can be met The administration's budget requests for fiscal years 1996 and 1997 were structured to support adequately the required analyses and research needed to address the key technical issues before the end of 1997. However, Congress has not appropriated funds at the requested levels. Therefore, research has been shaped to fit within the budget, rather than to meet the technical needs essential to making the critical decisions. The PNGV's aggressive timetable for completing concept cars by 2000 and production prototypes by 2004, requires the first set of component technologies to be narrowed down by the end of 1997. The selection of technologies will probably occur in 1997 as planned but, because of incomplete research and less than desired information, the risk of failing to meet PNGV's ultimate goals will likely be increased. In addition, promising technologies, like fuel cells, will not be sufficiently mature in 1997, and work will continue to be required on this promising propulsion system beyond the PNGV time frame.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE,
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q2. Can you comment on the level of progress of goals 1 and 2 of the PNGV initiative?

A2. As noted in the National Research Council's Report, goals 1 and 2 do not have specific performance metrics, and, consequently, are not amenable to precise measurement of progress. However, there is anecdotal information demonstrating that substantial progress has been made on goals 1 and 2 in the three years since PNGV was established. In our written testimony, we cited a number of examples of goal 1 and goal 2 accomplishments from the Department of Energy. In addition, the report *PNGV Technical Accomplishments* contains a substantial number of projects that bear on goals 1 and 2. Of the sixty-five accomplishments listed in the report, roughly twenty-six relate to goal 1 and eleven to goal 2.

Q2a. How much of the funds have been devoted to these two goals?

A2a In fiscal year 1996, nearly all of DOE's $121 million funding for PNGV is from the Office of Transportation Technologies (OTT), which is in the Office of Energy Efficiency and Renewable Energy. Consistent with its mission of reducing America's dependence on imported oil, OTT's efforts are focused on goal 3--vehicles with fuel efficiency of up to 80 miles per gallon. However, there are a number of PNGV activities that support goals 1 and 2 that match well the mission of other DOE offices. In fiscal year 1996, about $14 million of DOE funding is related to accomplishment of goals 1 and 2.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q3 According to the NRC review and discussion by the PNGV technical working group, cost reduction and safety are issues often listed as highly critical technical barriers needing further "research" However, while these items may require research, often they involve manufacturing and engineering issues that are directly related to the competitiveness of the performer. Do you have or can you propose criteria for determining which areas of such research really warrant government funding?

A3 The criterion used by the Department of Energy to determine which areas of research to pursue applies to all PNGV projects that support goal 3: DOE supports research on high-risk enabling technologies that are consistent with the department's mission of significantly improving the nation's energy efficiency. In some cases, research on high-risk enabling technologies for PNGV may include efforts related to manufacturing and engineering to remove technical barriers that are critical to achieving the partnership's goals. However, emphasis is given to technology development efforts that are generic or pre-competitive, while near-term improvements in conventional technologies or products and commercialization activities, are principally industry's responsibility.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q4 How do you respond to the review comments by the PNGV standing committee of NRC, which aside from the specific technical recommendations, point out the following shortcomings of the PNGV programs:

Q4a Lack of a single technical program director for the PNGV government management or the USCAR.

A4a In partial response to the Peer Reviewers' recommendation, a government Technical Council was established by the PNGV Secretariat, at the Department of Commerce, to improve federal oversight, and support to the technical teams. In addition, each of the federal agencies that participates in PNGV has a representative on the Operational Steering Group (OSG). However, because each of the agencies has its own unique mission, we believe the collegial and collaborative approach of the Technical Council is preferable to identifying a single government technical program manager to direct the work within each agency. The PNGV is not just a partnership with the auto industry, but also represents an historic level of collaboration among federal agencies in support of a critical national need.

Similarly, we have found no difficulty with working in partnership with the automakers' three technical directors, and we continue to agree with their position that the partnership would not be well served by establishing a single technical director at USCAR.

Q4b Lack of an empowered management structure at DOE and DOC to affect the array of federally funded projects.

A4b Since the Peer Review Committee met with the PNGV officials last year, the government has expanded its management team to include a Chief Financial Officer for PNGV. He works in the Office of Management and Budget. This official will partly address the committee's concerns about the project's ability to focus funding in necessary technical areas. Within the Department of Energy, we recently reorganized the Office of Transportation Technologies to bring nearly all of the department's PNGV projects under the direction of a single office, the Office of Advanced Automotive Technologies. This move was designed to streamline management of PNGV projects, and to facilitate direction of resources to the most promising technical areas.

Q4c The need for more support and involvement in the PNGV research program by NASA, DOD, and DOT.

A4c All of these agencies are fully committed to the success of PNGV and are participating to the extent their budgets allow. The National Aeronautics and Space Administration (NASA) has funded the systems analysis work and NASA personnel continue to participate and collaborate in a variety of PNGV technical activities.

It is our understanding that the principal difficulty with the involvement of DOT and NASA is a lack of funding appropriated by Congress. Moreover, although the Department of Energy's fiscal year 1996 budget request included funds to begin a collaborative effort with DOT's National Highway Traffic Safety Administration to evaluate crash behavior of vehicle structures fabricated from lightweight materials, Congress did not appropriate any funds for this project. We understand both DOT and NASA are continuing to discuss PNGV funding with their appropriations committees as the fiscal year 1997 budget process proceeds.

All of DOD's research is in support of its defense mission. The DOD is nevertheless an important partner in PNGV because, in several areas, its mission-oriented research is directly relevant to PNGV's goals. Reduced weight and fuel efficiency are important to military vehicles as they are to the civilian passenger fleet. The DOD research in these areas is available to the PNGV project. The Department of Energy is continuing to work in close collaboration with DOD's Defense Advanced Research Projects Agency on power sources and with the Office of Naval Research on electronic power systems.

Q4d The need for analysis of current and post-PNGV technologies, overall system analysis, a well-defined and detailed program plan and adequate resource allocation.

A4d Systems analysis of current and post-PNGV technologies is on-going; development of the initial software tools is planned to be completed by December 1997. To date, the software has been developed and validated against software tools developed by the automakers and DOE national laboratories. A revised PNGV Program Plan, covering all three goals in well defined detail, was completed in November 1995. Finally, the government has expanded its management team to include a Chief Financial Officer for PNGV, who is employed in the Office of Management and Budget. This official will help address the committee's concerns about the partnership's allocation of federal resources.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q5 How would you respond to a Congressional requirement to establish the review process, such as the existing NRC review, as a permanent part of the PNGV program?

A5 Such a Congressional requirement would be unnecessary--the Peer Review is called for in the PNGV Declaration of Intent. Moreover, both the government and industry recognize the value of an annual peer review, and fully intend to continue the existing relationship with the NRC.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q6 The PNGV program is more than three years old, yet an important component, namely an overall system analysis (also emphasized by the NRC panel) has not been accomplished.

Q6a How can you have any certainty in your success given the lack of such capability?

A6a. From its outset, the partnership has relied on systems analyses as one of the important approaches to help guide decision making on vehicle and subsystem design. Chrysler, Ford, and General Motors each has its own systems modeling team to guide technology decisions. In addition, there is an independent systems analysis underway funded by the government; development of the software tools is expected to be completed by the end of calender year 1997--in time to support the planned technology selection.

Q6b. Would it not be more desirable to perform an overall system analysis that can be used as a "design/system performance evaluation"? Why?

A6b. The industry has always recognized the essential role of overall systems analysis in achieving vehicle and component development objectives as evidenced by a considerable and growing dedication of resources to modeling and computer analyses of vehicle designs. Discussion with the federal agencies involved in the systems analysis effort have reaffirmed that PNGV's systems analysis will remain a priority. All of our plans described in PNGV's Technical Roadmaps reflect this priority.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q7 How do you respond to the criticism raised in the NRC's review of the program management. Please specifically respond to the suggestions by Dr. Hirsch, of the Standing Committee, and Prof. Sperling that DOE should be the lead agency in the PNGV program.

A7. Since the Peer Review Committee met with PNGV officials last year, the government has established a Technical Council to improve oversight and coordination among agencies, in relation to activities of the Technical Teams. Though the major portion of the government's funding is provided by the Department of Energy, DOE's efforts are focused principally on research and development that supports PNGV's goal 3. Coordination of the government's role with respect to the combination of the three of PNGV's technical goals is most appropriately located in the Department of Commerce, which has always maintained a substantial role in supporting non-military technology development.

Professor Sperling, citing DOE's major responsibilities and technical expertise, suggests DOE be given control of PNGV's goal 3. However, he seems to downplay the substantial expertise in other federal agencies that support goal 3, for example, in the area of lightweight materials. Moreover, the Department of Energy retains full responsibility for managing all of its programs that support PNGV. In light of the close interrelationship between PNGV's three goals, we believe it may not be practical to spread control for individual goals among several federal agencies.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q8 What are the most critical barriers, aside from cost reduction and hydrogen infrastructure issues, for the use of fuel cells in automobiles?

A8. For direct-hydrogen automotive fuel cells, critical technical barriers, aside from cost reduction and hydrogen infrastructure issues, include: (1) development of efficient, integrated thermal management processes for waste heat utilization, cooling, and humidification; and (2) development of an integrated fuel cell system, including balance-of-plant components (compressors, humidifiers, sensors, and controls), that meet automotive specifications.

For automotive fuel cells using on-board liquid-fuel processing, critical barriers include: (1) eliminating poisoning of the fuel cell catalyst by small quantities of carbon monoxide (CO) from the fuel processor, and (2) reducing the size and complexity of the fuel processor. The Department of Energy is currently supporting research and development activities to increase the CO-tolerance of the catalyst, reduce the amount of CO from the fuel processor, and decrease processor size and complexity.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q9. Why doesn't the government attach a higher priority to developing a hydrogen infrastructure given the fuel cell potential?

A9. Though the Department of Energy recognizes the tremendous potential for fuel cells, the emphasis for the near term is on powering them with hydrogen-rich fuels, such as natural gas or methanol. The infrastructure required to provide hydrogen fuel, including production, transportation, distribution, storage, and delivery, is very costly to create, and government can have only limited impact on its development and deployment. However, many of the technologies under development for PNGV will be capable of running on a variety of fuels, including hydrogen, when it becomes more available and is cost effective.

Within the Department of Energy, the Office of Utility Technologies' Hydrogen Program is working with industry to develop hydrogen infrastructure technologies for a variety of hydrogen-related applications. These include looking at small-scale methane steam reforming systems and small electrolyzers as potential transition systems that could be available for early use with hydrogen-fueled vehicles. The Office of Transportation Technologies' (OTT) Fuel Cell Program is working closely with DOE's Hydrogen Program to identify appropriate infrastructure architecture for automotive fuel cell applications Further advancement in fuel cell technology will facilitate and accelerate the evolution of a hydrogen infrastructure Key elements of OTT's program include on-board hydrogen storage and on-board processing of liquid fuels, such as methanol, to produce hydrogen-rich gas to power a fuel cell In addition, OTT is supporting the deployment of natural-gas powered vehicles, which, in terms of required infrastructure, could be one possible precursor to hydrogen-fueled vehicles.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q10. We understand that MAN, a major European bus manufacturer, BMW and Daimler-Benz, as well as Mazda, in Japan, are demonstrating conventional hydrogen-burning internal combustion (IC) engines.

Q10a. Is a hydrogen-fueled IC engine being considered for PNGV and if not, why?

A10a. At this point, PNGV is considering a variety of propulsion options. The PNGV program will develop an automotive technology that triples fuel economy and has widespread application. To achieve widespread application, the initial focus is on available fuels, i.e., gasoline and diesel. However, the technologies being developed under PNGV will have the capability to operate on a variety of fuels. Alternative fuels, including hydrogen, may be used in the future as they become more available and cost-effective. The DOE's Office of Utility Technologies is supporting research involving hydrogen-powered IC engines. The focus of the work is on the safe, low-temperature, on-board storage of hydrogen for use in an internal combustion engine in a hybrid-electric configuration.

Q10b Are hydrogen infrastructure issues easier to solve in Europe or Japan than in the U.S.?

A10b. The relatively higher cost of gasoline in Europe and Japan could provide a greater incentive for establishment of alternative fuel infrastructures . In addition, Germany has a pipeline that supplies hydrogen for industrial purposes; proximity of that pipeline to transportation applications could facilitate the development of a hydrogen infrastructure in Germany.

Q10c Has there been any study to determine the feasibility of developing such an infrastructure?

A10c. The Office of Utility Technologies' Hydrogen Program has conducted a number of studies to assess the feasibility of developing a hydrogen infrastructure. It has determined that reforming natural gas at end user sites is a cost-effective means to develop a near-term hydrogen infrastructure. Other feasibility studies are in progress as part of PNGV. For example, Directed Technologies, Incorporated, will deliver a hydrogen infrastructure study in September 1996, under the DOE/Ford fuel cell contract.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q11. Please describe the hybrid electric program at DOE and the role and extent of the three contracts with GM, Ford and Chrysler.

A11. The U.S. Department of Energy (DOE) is working closely with other Federal agencies and key auto industry partners to develop hybrid electric vehicles (HEVs) as a practical way of providing clean and efficient transportation for the future that will significantly contribute to reducing our nation's growing dependence on imported oil. Hybrid Electric Vehicle R&D is a key component of DOE's Advanced Automotive Technologies Program, and is a priority effort in DOE's support of PNGV's goal 3. The focus of the HEV program is on three strategic objectives:

1. Develop a production-feasible hybrid propulsion system by 1998 that would enable market introduction of a 50-mpg light-duty vehicle by 2003.
2. Develop a production-feasible hybrid propulsion system by 2004 that would enable market introduction of an 80-mpg light-duty vehicle by 2008.
3. Conduct pre-competitive R&D of critical and higher risk components and subsystems that can enhance HEV performance, reliability, and cost-effectiveness.

The 50-mpg and 80-mpg fuel economy targets represent double and triple fuel economy improvements relative to current 6-passenger family sedans. In addition, the HEV technology must meet Tier II light-duty emission standards; be consumer acceptable with respect to performance, range, safety, and cost; and support the introduction of alternative fuels.

Major propulsion subsystem technologies are currently being developed under DOE cost-shared contracts with Chrysler, Ford and GM. Each company is developing complete hybrid propulsion subsystems for evaluation in test mules, which are modified conventional vehicles. These test mules are scheduled to be delivered in FY 1998 and 1999. The purpose of these current contracts is to validate propulsion system technologies that yield up to 100% (50 mpg) improvement in fuel economy over today's conventional vehicles. The major technologies under development are heat engines (gas turbines, Stirling, and diesels), energy storage (high power batteries, ultra-capacitors, and flywheels), and power electronics. Major technology selection decisions have been made in every component area. Internal combustion spark ignition engines, wheel motors, fuel cells, flywheels, ultra capacitors, and all battery chemistries other than lead acid, have been eliminated from consideration for the 50 mpg vehicle system for the 1998 time frame (these technologies remain under consideration for PNGV's goal of 80 mpg). Factors supporting these decisions include both technical and business considerations.

Each program is described briefly below:

General Motors: GM is approaching the third and final phase of its hybrid propulsion system development contract. It is pursuing development of series hybrid vehicles only. The test vehicles will be based on converted Chevrolet Luminas. Several successively improved iterations are planned, culminating in the delivery of the Integrated Test Vehicle in December 1998. General Motors will now focus on advanced heat engine hybrid power units for the remainder of the program. For the other major components of the system, GM is receiving excellent support from its allied divisions, a high efficiency A/C system from Delphi-Harrison, electric power steering from Delphi-Saginaw, and an improved Impact traction motor from Delphi Energy Systems.

Ford Motor Company: Ford has very rapidly narrowed the technology focus of its program after evaluating many alternatives. It will develop parallel hybrid vehicles, based on advanced compression-ignition direct-injection (CIDI) engines, for testing in modified Ford Contours. Fuel cells, flywheels, and series hybrids have been eliminated from consideration for the propulsion system for the 1998/1999 deliverable. Steady progress is being made in development of the balance of system components. Ford has teamed with FEV Engine Technology to develop the high efficiency CIDI power unit. FEV is world renowned for its expertise in diesel engine R&D. The major challenges to the diesel for the hybrid application will be to meet the low emission targets and to achieve the low noise, vibration, and harshness levels that are typical of gasoline engines.

Chrysler Corporation: Chrysler is pursuing development of CIDI hybrids in a variable configuration that allows the vehicle to be operated in either series or parallel mode, depending on the driving conditions Chrysler will maintain only three carefully chosen team members, ITT Automotive, Detroit Diesel, and Delphi Energy Systems. Chrysler is presently in the process of finalizing its subcontracts, working with DOE and its lower tier subcontractors. Simultaneously, they are engaged in modeling and simulation work aimed at determining appropriate component specifications, control strategy, and performance predictions. Test vehicles will be based on a lightweight Neon platform.

The hybrid activity will be narrowed in scope and transitioned from propulsion subsystem technology development aimed at 50 mpg to high priority vehicle system technology development targeted at the 80 mpg goal, which support PNGV's goal 3. This will require a total vehicle systems level approach and discussions are currently continuing with the auto industry, and our other PNGV partners, on how to move efficiently into this next phase of hybrid vehicle activity.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q12. GM ($148 million) and Ford ($138 million) signed their 5-year Hybrid Vehicle (HEV) contracts with DOE in September and December of 1993, respectively. Chrysler's 4-year contract ($84.8 million) was awarded in February of 1996. While one can see that GM's and Ford's contracts can directly help goals 2 and 3 of PNGV (we also know that DOE's hybrid program has an aim of doubling fuel efficiency and producing production-feasible HEV by 1998). There seems to be very little time for Chrysler's program to get off the ground by the 1997 milestone, and certainly will not be completed by 1998. Why was this contract awarded, and why at such a later date in comparison to the other two contracts?

A12. The subcontract with Chrysler Corporation was signed in March of 1996. Its objective is to develop and demonstrate, by December of 1999, a production-feasible hybrid propulsion system for use in light-duty vehicles that will provide 50 mpg energy efficiency and low emissions. The signing of this contract is a major milestone toward achieving the goals set out by the Partnership for a New Generation of Vehicles (PNGV). As a major domestic automobile manufacturer, Chrysler Corporation's commitment to the partnership is considered an important element by both the government and private sector parties responsible for the PNGV. Its involvement will ensure that all three of the hybrid propulsion systems development efforts will be carried out in parallel by teams composed of many component developers and suppliers that are engaged in achieving advanced automotive technologies. These teams are led by the domestic automotive industry, and will help achieve the nearer term 50 mpg milestone, but many will also be major contributors in helping to achieve the PNGV target of 80 mpg by 2004.

In addition, Chrysler Corporation has proposed a unique hybrid propulsion system that uses advanced materials and components not under investigation by the other existing programs. Chrysler has proposed several other innovative approaches, not otherwise available, to solving the engineering challenges in hybrid propulsion system design.

Although Chrysler Corporation started about two years behind the other two subcontractors, they have benefited greatly from the experiences of both GM and Ford in the first two years of the hybrid program. As a result of this collaboration, Chrysler will be able to emphasize the most viable technology options rapidly without the more expensive and broader-based process that Ford and GM had to undertake. Moreover, Chrysler's ability for rapidly bringing new and innovative products to market, through a lean and agile management and manufacturing approach, will increase the likelihood of meeting the goals of the program within its time schedule.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q13. Is the reduced-scale fuel cell research (in transportation) more of an application and sizing problem, or are there genuine technical and research issues that need to be resolved?

A13. Development of proton-exchange-membrane fuel cell powerplants for automotive applications requires resolution of significant technical and research issues. The technical challenges that must be overcome relate to the fuel cell stack, the fuel processor, and the important balance of plant components. Examples of fundamental challenges that are independent of the automotive application include fuel processors with an inherent load following capability and improved materials and designs for cost reduction. Examples of research needs include development of enhanced non-precious metal electrocatalysts, improved corrosion-resistant materials for bipolar plates, and improved selective oxidation catalysts for achieving necessary fuel-stream purity. In addition, the automotive requirements demand resolution of technical issues that include: rapid start-up, system power density improvements to meet packaging constraints, system integration, durability and reliability, and materials cost reduction.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q14. You seem to agree (according to your testimony) with the NRC's assertion that fuel cells are beyond the time-table of PNGV, yet Daimler-Benz has announced an actual demonstration vehicle in-line with ultimate PNGV goals. Are you willing to reconsider your assessment of fuel cells?

A14. The National Research Council's (NRC) report strongly supports the continued development of automotive fuel cells. While the report states that, depending on progress in the next two years, the PNGV may find it necessary to restructure the program extending the schedule, they do not as yet assert that fuel cells are beyond the PNGV timetable. In our testimony, we indicated that hydrogen-powered fuel cell vehicles are likely to be commercially viable only beyond the ten-year time frame of PNGV, because of a lack of a hydrogen fueling infrastructure.

The Daimler-Benz announcement of a new fuel cell powered demonstration vehicle, dubbed NeCar II, is a clear indication of how rapidly fuel cell technology is progressing. It is a vehicle designed to show the promise of fuel cells and the significant progress made in the year since NeCar I was introduced. Even so, Daimler-Benz has indicated that it is still too early to say when fuel cell vehicles will reach production. The PNGV is actively pursuing research on fuel cells--one of the critical energy conversion options included in the partnership's program. The partnership's activities address the primary issues to make fuel cells commercially viable, and we agree with Daimler-Benz that it is still too early to say when fuel cells will reach production readiness. The decision on which propulsion technology to carry forward in the PNGV program, in the context of the original time frame, is to be made in 1997.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q15. Light Duty Engine R&D (vol. 4 of 5, p. 324 of the FY 97 DOE budget request) list $8,300,000 for Advanced Automotive Piston Engine R&D in order to "support technologies applicable to 2 to 3 times improved vehicle fuel efficiency...". The PNGV program has determined that a 3 times efficiency will only be achieved with a hybrid vehicle and some 30 to 40% total vehicle mass reduction.

Q15a. Why do we need to spend additional resources to improve current piston engine technologies?

A15a. To obtain three times fuel efficiency, we need to substantially improve engine efficiency as well as reduce vehicle mass. In fiscal year 1997, the Advanced Automotive Piston Engine R&D Program will focus on technologies that support PNGV's goal 3. The principal activity in the program is R&D related to compression-ignition, direct-injection (CIDI) piston engines. This activity is integrated with DOE's hybrid electric vehicle program. The CIDI engine is the most efficient internal combustion engine. It is a prime candidate to power hybrid-electric vehicles, which have the potential to meet PNGV's goal of fuel efficiencies of up to eighty miles per gallon. A small portion (less than twenty-five percent) of the budget request for the Advanced Automotive Piston Engine R&D Program supports cooperative research and development agreements (CRADAs) between DOE's national laboratories and the Low Emissions Partnership--a consortium of Chrysler, Ford, and General Motors. These CRADAs deal with improvements in conventional piston engine vehicles, for example, catalytic converters for lean-burn engines. Though nearer term, many of these projects will have direct application in advanced engines for hybrid-electric vehicles.

Q15b. How does this fit Goal 2 of PNGV?

A15b. The PNGV's goal 2 is to "implement viable innovations from ongoing research to conventional vehicles." Though the Department of Energy's primary emphasis in PNGV is on goal 3--vehicles with fuel efficiencies of up to eighty miles per gallon--the department supports a few goal 2 activities that take advantage of unique capabilities at DOE's national laboratories These projects will lead to near-term improvements in fuel efficiency, and reductions in emissions of standard vehicles. As demonstrated in the automakers' recent report, *PNGV Technical Accomplishments*, many of these goal 2 projects have already produced a number of PNGV "success stories."

Q15c. Does this indicate a lack of coordination within DOE and lack of proper priority given to the PNGV program?

A15c. No it doesn't. The Department of Energy's Advanced Automotive Piston Engine R&D Program is an integral component of the R&D activities managed by the Office of Advanced Automotive Technologies, and an important part of the Partnership for a New Generation of Vehicles (PNGV). Moreover, PNGV remains a high priority within the Department of Energy. Reflecting the department's priorities, the major portion of activities in the Advanced Automotive Piston Engine R&D Program support PNGV's goal 3--vehicles with fuel efficiencies of up to eighty miles per gallon. A small portion supports near-term improvements in conventional piston engines (goal 2), many of which are closely related, and could have direct impact on, engines being developed to meet PNGV's goal 3.

QUESTIONS SUBMITTED FROM THE COMMITTEE ON SCIENCE, SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

Q16. **What is the level of participation by the DOE's laboratories?**

A16. The Partnership for a New Generation of Vehicles (PNGV) brings together the resources of the federal government, national laboratories, universities, and industry, to meet a critical national need. As clearly demonstrated in the automakers' recent report, *PNGV Technical Accomplishments*, DOE's national laboratories are playing a significant role in all aspects of PNGV: fifty of the sixty-five accomplishments identified in the report reflect work involving DOE's national laboratories. To stimulate increased collaboration among the automakers and DOE's national laboratories, PNGV has sponsored a series of tours and workshops at each of the laboratories. In fiscal year 1996, about 30 percent of DOE's funds for PNGV support researchers at national laboratories. The Department of Energy is continuing to work closely with all PNGV partners, to assure the resources of DOE's national laboratories are fully engaged in support of the partnership's goals.

Bob Mull
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August 23, 1996

Ms. Jennifer Disharoon
Staff Assistant
Subcommittee on Energy and Environment
B-374 Rayburn HOB
Washington, DC 20515

Dear Ms. Disharoon,

In response to Chairman Rohrabacher's letter of August 8, we are forwarding responses to the questions submitted by the Subcommittee on Energy and Environment and its members. Please let me know if we can be of further assistance.

Bob

QUESTIONS FOR ROBERT F. MULL

1Q. We understand that GM has signed about 42 Cooperative Research and Development Agreements (CRADAs), while Ford and Chrysler, together, have less than 10 CRADAs with the National Laboratories.

A. These numbers appear somewhat high. Since most single-company CRADAs pre-dated PNGV, they set the stage for PNGV and other similar collaborative activities today. GM entered into more CRADAs because it began working with the national labs earlier than Ford or Chrysler. Most GM CRADAs have either been completed, are near completion, or have been converted to collaborative CRADAs with the other two auto companies.

a) How have these CRADAs served the corporations?

CRADAs serve the corporations by leveraging resources to meet coincident technical objectives within aligned mission areas of industry and government. Leverage occurs when complementary technical minds work toward common solutions in a cost-effective, interactive relationship. CRADAs improve skills of both industry and federal lab participants.

b) What level of funding is being contributed from the corporations, and what is the level of contribution from the National Laboratories?

CRADAs typically require a 50-50 resource allocation between industry and laboratory. Government funding of CRADAs is used exclusively to support the federal laboratories and no government funds go to industry.

2Q. USCAR has signed (as of July 1995) 42 CRADAs with the national laboratories. Do these CRADAs include those signed with the individual corporations referenced in question 1?

A. Currently, our records indicate that USCAR has 38 signed CRADAs with the federal laboratories. All USCAR CRADAs are signed by each of the three companies. These USCAR CRADAs are incremental to the individual company CRADAs referenced in Question 1. However, some of the CRADAs that are now being executed by USCAR are conversions of earlier single-company CRADAs.

a) What are the pros and cons of dealing with the National Laboratories?

Dealing with the National Laboratories provides an opportunity to effectively utilize unique federal resources and facilities. It offers the auto companies access to expertise in technologies related to PNGV goals that are not traditionally available within the automotive industry, such as fuel cells, advanced materials, ultracapacitors, and flywheels.

In addition, the alignment of independent but complementary research efforts already underway accelerates technological progress. Collaboration blends the laboratories' high technology fundamental research knowledge with industry's ability to develop affordable solutions to real-world problems.

Completing multi-year programs with laboratories whose program funding is no longer stable has become a significant challenge. In fact, our companies are facing premature termination of several important multi-year joint projects because laboratories have lost their funding. It has also proven difficult at times to identify research projects underway within the government R&D complex which may be applicable to PNGV technical challenges. For PNGV collaborative projects to be viable, they must align with lab missions.

b) Are uniform cooperative R&D procedures in place, or does each laboratory have its own set of procedures?

Originally, each DOE laboratory had its own preferred contract language for CRADAs. However, the industry and DOE have worked together to develop a standardized DOE CRADA (master CRADA) that has simplified establishing new projects. USCAR and the Army (but not DOD as a whole) have also agreed to a standardized CRADA. Additional efficiencies can be achieved by expanding the master CRADA to include all federal laboratories and agencies.

3Q. Why do the Big Three seem reluctant to pursue the higher risk technologies, such as fuel cells and hydrogen-fueled Auxiliary Power Units (APUs), when one of the key justifications for the industry/government partnership is development of high-to-medium risk technologies?

A. The industry is actively pursuing a broad cross-section of high risk technologies that have the potential to revolutionize the automobile as we know it. The following are some examples of high risk technologies (including the affiliated laboratory) under investigation within PNGV:

- **Fuel cells** -- Ford/ direct hydrogen-fueled PEM (LANL) and GM/reformed methanol PEM fuel cell.
- **Hydrogen storage and fuel reforming** -- Chrysler/multi-fuel processors (LANL); Ford/on-board hydrogen storage using lightweight pressure vessels (LLNL); GM/ methanol reformation.
- **Gas turbine and stirling engines** -- GM/Allison ceramic gas turbine & Stirling Thermal Motors; Ford/Teledyne Ryan and Allied Signal gas turbines.
- **Flywheels** -- Ford/Unique Mobility; Chrysler/Satcon. Note: GM flywheel work with LLNL and Trinity suspended until safety issues are adequately resolved.
- **Advanced batteries and Ultracapacitors** -- USABC approached Sandia for defense-related materials synthesis and advanced battery expertise regarding lithium-ion batteries. Saft is also working on lithium-ion; lithium polymer work underway with 3M and Hydro-Quebec. Similarly, USABC is coordinating advanced work on ultracapacitors with labs and suppliers.
- **Advanced Materials** -- USCAR work on composite crash energy management (with LLNL, ANL, LANL, SNL, Y12); adhesive bonding (ORNL), durability (ORNL); casting

aluminum and magnesium (ORNL, LLNL, SNL); stainless steel body structure (Armco and Autokinetics), SRIM/composites (NIST). Ford and Chrysler concept vehicles feature 100% aluminum unibody construction; GM EV1 uses polymer composites and aluminum in the suspension; all companies are working with Armco/ Autokinetics.

However, many of these technologies have considerable challenges to overcome before they can be considered for use on passenger vehicles.

4Q. According to the latest "Fortune 500" survey (Fortune, April 29, 1996, p. F-1), the 1995 Big Three revenues exceeded $359 billion, and profits were more than $13 billion. We also understand that total R&D spending by the Big Three exceeds $12 billion with GM and Ford spending about 80% of the total. Why should U.S. taxpayer funds contribute to the R&D of such profitable private sector firms?

A. The technologies under development, such as fuel cells, gas turbines, energy storage devices, advanced internal combustion engines, and advanced lightweight materials have many applications in public and transportation sectors. For example, fuel cells are used by NASA to power its space shuttles and could potentially be used as a silent propulsion system for military vehicles.

The focus is on high-risk, breakthrough technologies that are critical if meaningful progress is to be made on key national goals including improved environmental quality and reduced dependence on imported oil. Demand for most of these advanced technologies is not market-driven and consequently offers little opportunity for the near-term tangible returns necessary to private industry. Government involvement and funding is a necessary and appropriate ingredient to support progress on societal goals that are not driven by current customer demands.

PNGV strategically aligns the goals of manufacturers and suppliers with those of federal agencies and labs that are engaged in similar or complementary research efforts. Significant efficiencies are realized through coordination of a large number of previously separate or independent projects into a cohesive research program.

Finally, it is important to note that most of the federal funds allocated to this program do not go to the OEM manufacturers. Most of these funds go to federal labs and industry suppliers.

5Q. Some auto companies estimate that more than half of their research dollars are devoted to projects related to meeting government regulations.

a) How does the PNGV initiative improve the regulatory environment between the industry and government?

A. The PNGV process recognizes that industry and government share responsibility for achieving societal goals that exceed -- or run counter to -- customer demands. It offers the possibility of breakthrough technology and demonstrates that meaningful progress can be made through cooperation rather than mandates.

Essentially, the PNGV initiative offers an opportunity to supplement and replace the old command-and-control regulatory mechanisms with a cooperative approach that achieves results without distorting the market, compromising consumer needs, or costing jobs. We believe that industry and government jointly can achieve far more by working together through a science-based process than through traditional adversarial approaches to problem resolution.

b) Why is safety not more prominently addressed in this initiative?

Safety is a critical component in the PNGV technical roadmap. The need to vastly reduce vehicle mass increases enormously the challenge of achieving equivalent safety performance in breakthrough vehicles. The addition of sophisticated energy storage devices such as flywheels and high-power batteries further increases the safety objective. The industry believes that ensuring the safety of advanced vehicles will be one of the greatest technical challenges of the program. Accordingly, safety issues are key criteria for all candidate next-generation technologies (see response to question on safety posed by Representative Wamp).

6Q. We understand that many small businesses and some universities find it difficult to participate in the PNGV program. What mechanisms do you offer that allow such involvement and protection of innovative concepts proposed by small companies?

A. We have established mechanisms and targeted programs for small suppliers and universities. There are some 400 suppliers (universities, laboratories, and large as well as non-traditional companies) involved with PNGV. We are expanding the involvement of second and third tier and non-traditional suppliers. There are numerous outreach efforts for these constituents, urging and easing participation. Examples include:

- Inventions Needed for PNGV is a recent publication used to solicit ideas and to inform interested third parties on how to become involved. It is also available on the Internet.
- We have held "outreach" workshops this year on the following topics: CIDIs, aluminum, chassis materials, fuel cells and manufacturing, electrochemical energy storage, and electronics and electrical systems.
- Symposia have been held in Washington, DC to bring together the nation's experts in such areas as fuel cells, advanced materials, electrical and electronics, and energy storage.
- The Future Car program involves universities and numerous suppliers.
- The government's Small Business Innovative Research (SBIR) program and Energy Related Inventions Program (ERIP) enable small suppliers to become involved in PNGV-related research.
- NSF welcomes university proposals on PNGV topics subject, of course, to normal peer review.

Innovative concepts are protected by normal legal processes as in any research collaboration.

7Q. Will the PNGV program be able to meet all of the technical requirements needed for the 1997 milestone of selecting the most promising technologies?

A. We have many areas of high technical risk in the program, largely due to the enormous challenge and the constraints on resources available to pursue goals.

In the words of the Peer Review Panel, "Despite progress, there is still a wide gulf between the current status of major vehicle systems and subsystems and the performance and cost requirements necessary to meet major PNGV milestones, such as the 1997 technology selection. . . Some of the technical barriers to achieving PNGV objectives can probably be overcome with sufficient technical breakthroughs."

We are awaiting critical data from ongoing studies of several technologies that will help to answer this question. There are significant technical barriers to be addressed in every candidate technology, and no solutions currently present themselves as obvious choices. We still intend to select, using the then best available information, those technologies that are sufficiently mature to proceed with validation in concept vehicles near the end of 1997 as originally planned. While we should certainly be able to select the most promising technologies, there is no guarantee that the technologies selected will achieve long run program objectives.

8Q. On May 14, 1996, Daimler-Benz presented its second generation fuel-cell powered demonstration vehicle (NECAR II). None of the concept cars presented in the "PNGV Technical Accomplishments" have a fuel-cell powered propulsion system. Has the U.S. already fallen behind, even though we initiated the PNGV program?

A. The U.S. has not fallen behind. The Daimler-Benz demonstration vehicle is a small van powered by a fuel cell and fueled by compressed hydrogen gas carried in high-pressure, composite tanks mounted in the roof above the passengers' heads. The fuel-cell stacks were designed by Ballard Power Systems of Vancouver (Canada), an internationally recognized leader in fuel cells. Ballard Power Systems and other fuel-cell developers are also working with the U.S. companies under PNGV, so we have access to that same technology. In addition, partner laboratories and companies under PNGV have developed lightweight composite fuel tanks, so a van equivalent to the Daimler-Benz vehicle could be assembled. PNGV partners are also working on processors to allow fuel cells to run on methanol and other liquid fuels now available within the U.S. infrastructure. Additional projects are under way to optimize the performance of fuel cell stacks and their associated auxiliary systems for improved packaging in the limited space available in passenger cars.

9Q. We understand that MAN, a major European bus manufacturer, BMW and Daimler-Benz, as well as Mazda, in Japan, are demonstrating conventional hydrogen-burning internal combustion (IC) engines. Is a hydrogen-fueled IC engine being considered by PNGV and if not, why?

A. The industry has studied both hydrogen-fueled conventional engines as well as other uses of hydrogen such as in fuel cells. There are two principal impediments to adoption of hydrogen in conventional vehicles: first is the safety and packaging difficulties of storing hydrogen on-board; second is the absence of an efficient infrastructure to supply hydrogen to the motoring public. If we are successful in resolving the on-board storage challenges for either conventional or breakthrough applications, we believe that infrastructure issues could be resolved over time by the government working with independent energy suppliers.

It is important to note that the use of hydrogen as a substitute fuel for gasoline in a combustion engine does not solve the problem of nitrogen oxide (NO_x) emissions. NO_x is formed when combustion takes place in the presence of air, regardless of the type of fuel being burned. Therefore, a hydrogen-fueled conventional engine will still require aftertreatment devices such as a catalytic converter to reduce NO_x emissions. In contrast, hydrogen fuel cells, where energy is generated via an electrochemical reaction, do not produce harmful side products such as NO_x.

10Q. You mentioned a leap-frog technology developed for the diesel engine, being considered for the APU, that would be far ahead of the European diesel engines. Can you provide any specific information abut this "leap-frog technology" that would make diesel a promising choice despite the NO_x and particulate emission problems of current diesel engines?

A. The primary four-stroke, direct-injection approach being pursued uses high-speed, four-valve diesel technology. We are working toward the "breakthrough" combination of very high fuel economy and very low emissions that could achieve the PNGV goals utilizing advances in electronically-controlled, common-rail fuel injection, lean-NO_x catalysts, and very fast actuating electronically controlled boost and exhaust gas recirculation systems. The level of exhaust emissions, performance, low weight, and low noise that must be achieved is far beyond the state-of-the-art that exists in diesel technology anywhere in the world today. In particular, compliance with U.S. Federal Tier II and California ULEV NO_x emissions standards requires a four to five fold decrease in NO_x emissions versus current production diesel engines. In addition, the PNGV program is targeting noise levels equivalent to today's advanced gasoline engines and weight reductions of 25-30% versus today's production diesel engines.

11Q. You have provided a single unified testimony on behalf of the USCAR; yet, each of the USCAR corporations is pursuing separate concept vehicles and differing technologies. What is the justification for not pursuing development of a single prototype vehicle?

A. The USCAR participants are collaborating, on a pre-competitive basis, on the enabling technologies for PNGV, as depicted on the organization chart shown as Attachment IV of the filed testimony. For the initial phase of hybrid propulsion systems, we have agreed to develop unique approaches and to share information on the results. This clearly is efficient and productive for what we are trying to accomplish.

We think that it is appropriate, with the uncertainties that exist at this early stage of research, that more than one competing set of technologies be carried forward and validated in separate concept vehicles. Further, in addition to the pre-competitive technologies that we have worked on jointly, each company will be including proprietary technologies and design concepts in these vehicles. Therefore, from the onset, we agreed that we would build separate concept vehicles and propulsion systems.

12Q. You state in your testimony that "most of the government funds are re-directed to suppliers."

a) What are the total government funds received by the Big Three, and what percentage is re-directed?

b) What is your total cost-sharing?

A. For example, in FY '97 DOE-PNGV budget, the Big Three expect to receive approximately $12 million of government funding on a net basis. Suppliers receive an additional $65 million of government funds either on a pass-through basis from the Big Three or as direct contracts from DOE. Total cost sharing by the Big Three related to the DOE-PNGV programs amounts to another $29 million. Industry invests a substantial additional amount in collaborative work and proprietary R&D programs within each company relevant to PNGV objectives in addition to these cost-shared contracts. Total FY '97 spending from all government sources is expected to fall within the range of $175 million to $200 million pending final budget approval and determination of the relevance of certain agency programs to PNGV technical objectives.

13Q. In your testimony, you refer to the effect of some programs being cut prematurely due to variations in the federal PNGV budget. To which specific programs are you referring to?

A. Earlier this year, the Department of Energy's (DOE's) Defense Programs Office (DP) indicated that its technology transfer efforts with USCAR would be "realigned" in the transition from fiscal years FY '96 to FY '97. This action threatens substantial reductions and premature termination of over a dozen Cooperative Research and Development Agreements (CRADAs). Pending clarification from DOE, our records indicate that affected CRADAs include the following: "Reliability of on Board Diagnostics," "Exhaust Gas Sensors," "Thermal Spray Coating," "Adaptive Engine Controls," "Manufacturing Process Controls," "Supercomputing," "Superplastic Forming," "Welding of Thin Metal Sections," "Lean NO_x Catalysis," "DI Engine Combustion," "Life Predictor Assessment," and "Reducing Noble Metal Utilization."

In addition, NASA has been supporting the very important systems analysis efforts mentioned by the NRC Peer Review panel. This work is critical to the decision process but continued support by NASA is uncertain.

14Q. You stated in your testimony that the industry/national laboratory relationships are very strong and beneficial. Would the auto-makers directly make financial arrangements to fund the PNGV projects at the Laboratories in the absence of federal funding?

A. The industry has stated that its commitment to the principles of PNGV will survive any future reductions in federal spending. We believe that the objectives of PNGV are sufficiently important that they transcend near-term political or fiscal priorities because they offer an opportunity to reduce the impact of the automobile on society without compromising the public's demand for personal mobility.

However, it is important to recognize that the elimination of federal funding will have adverse effects on the timing and potential success of the program. While some technologies would continue to be pursued aggressively, the industry isn't prepared to fully fund the very high-risk long-term research where commercial viability is highly uncertain (and thus where the opportunity to earn back the investment is very risky). The cost sharing arrangements of the current projects, where government bears the larger share of the most risky long-term research activities, reflect this fact.

It is difficult to predict which efforts at the national laboratories, if any, would continue to be funded by industry, or would be available, in the event of a loss of federal funding. The industry would continue to search for the best technologies regardless of source.

15Q. Would you support the NRC review as a permanent annual peer review of the PNGV program to ensure its continuity and impartiality?

A. Industry and government agreed in the PNGV Declaration of Intent to an on-going peer review of the technical program by a mutually-acceptable, unbiased organization, such as the National Academy of Sciences.

16Q. Do you consider critical technical barriers such as safety and cost reduction as research topics or engineering problems?

a) How do you differentiate between those engineering solutions that would require research and those that may simply require re-tooling or re-design?

b) Why should the government fund programs solely aimed at cost reduction?

A. Reducing costs for most of the advanced PNGV technologies in order to produce affordable vehicles is not simply a matter of "scaling up" or "fine tuning" existing manufacturing processes. Rather, major advances in our scientific understanding of controlling phenomena must be made in addition to conceiving substantial technological innovations to effect the large cost reductions required to make the new technologies in high volumes while maintaining high quality and safety. Government funding is not applied for re-designing or engineering within existing (known) technology.

Government participation in this aspect of PNGV research is entirely appropriate for several reasons. First, in many cases these efforts constitute the pursuit of knowledge as basic as any in science. Second, it is frequently not possible to separate how something performs from the process used to make it, e.g., composite materials or ultracapacitors. Attacking the root cause of high costs is a legitimate scientific pursuit.

17Q. Composites are widely used in aerospace, boats and some automobiles. It appears that a great deal of PNGV research is aimed at cost reduction and high-volume manufacturing. Why should the federal government subsidize such commercial activities of the auto industry?

A. For composite materials to be viable for high-volume, highly-structural automotive applications as targeted by PNGV, they must be manufacturable reliably in high volume and at low cost in addition to meeting stringent performance requirements. This requires fundamental technical solutions and new approaches well beyond current state-of-the-art for composites in either aerospace or automotive use. Thus these are not "commercial activities of the auto industry" but rather part of developing composites as a viable enabling technology to support the PNGV goals. If we are successful in radically reducing the cost of composite structures, many nationally strategic industries will benefit.

18Q. Can an effective system analysis of PNGV concept vehicles be performed without having selected the technologies, or are you using system analysis as a "design/system performance evaluation tool" to assist in selection of the appropriate technologies?

A. Propulsion and vehicle systems analysis has been ongoing on at each company and has served as a building block for the PNGV systems analysis. However, systems analysis for a PNGV vehicle must include technologies (such as fuel cells, flywheels, etc.) that go beyond the auto industry's current knowledge base. Currently, a NASA-sponsored project is developing an advanced, comprehensive systems analysis tool by an independent contractor that includes these advanced technologies.

This advanced systems analysis modeling methodology is needed to estimate operational characteristics of a next generation vehicle without having to assemble prototype vehicle hardware. Using the best mathematical models available for each component -- various batteries, flywheels, engines, electric motors, etc., system performance for a given combination of these components can be assessed. In this way, systems analysis does assist in selecting the appropriate technologies for individual components, on-board vehicle systems, and overall vehicle design.

a) Why has this particular activity been delayed in the PNGV program?

The industry initiated systems analysis research at each company at the start of the program in addition to the work assigned to NASA and its sub-contractors. Delays in securing funding for outside contractors did not result in a slow down of internal, largely proprietary work.

QUESTIONS FOR PANEL 1 AND USCAR REPRESENTATIVES

1Q. Is it your understanding that the PNGV program is currently open and accessible to interested small businesses?

A. We have established mechanisms and targeted programs for small suppliers and universities in several agencies of the government. There are some 400 suppliers (universities, laboratories, and large as well as non-traditional companies) involved with PNGV. We are expanding the involvement of second and third tier and non-traditional suppliers. There are numerous outreach efforts for these constituents, urging and easing participation. Examples include:

- Inventions Needed for PNGV is a recent publication used to solicit ideas and to inform interested third parties on how to become involved. It is also available on the Internet.
- We have held "outreach" workshops this year on the following topics: CIDIs, aluminum, chassis materials, fuel cells and manufacturing, electronics and electrochemical energy storage.
- Symposia have been held in Washington, DC to bring together the nation's experts in such areas as fuel cells, advanced materials, electrical and electronics, and energy storage.
- The Future Car program involves universities and numerous suppliers.
- The government's Small Business Innovative Research (SBIR) program and Energy Related Inventions Program (ERIP) enable small suppliers to become involved in PNGV-related research.
- NSF welcomes university proposals on PNGV topics subject, of course, to normal peer review.

Innovative concepts are protected by normal legal processes as in any research collaboration.

2Q. How much of an emphasis is put on small business contributing new technologies and innovations to the program?

A. At present, we have about 400 organizations involved in PNGV, as the PNGV program includes many new enabling technologies and several small non-traditional firms. PNGV also includes a process for suppliers or private entrepreneurs to obtain information about the program and to submit their ideas. A recently published document entitled Inventions Needed for PNGV is being used to solicit ideas and to inform interested third parties on how to become involved.

3Q. How much of an emphasis is placed on small businesses filling a needed technical void under the PNGV's prevailing design plans?

A. The program is seeking breakthrough technology irrespective of source or geographic location. While the Partnership is sensitive that it needs to take special care to evaluate technologies from small entrepreneurial firms, its emphasis must remain on securing the best available technologies.

4Q. What mechanisms exist for new innovative technologies proposed by small businesses to be pursued if they are not being considered by the Big Three?

A. The government has several existing mechanisms that can help individuals and small businesses. Examples are the Small Business Innovative Research (SBIR) programs of every participating agency and the DOE-funded, NIST-executed Energy Related Inventions Program (ERIP). Beyond these programs, agencies are supporting work with smaller companies, without any direct participation by any of the USCAR partners. Examples include the seven ARPA regional consortia working on hybrid and electric vehicles and DOE CRADAs with various third parties.

5Q. Would it be a standard business practice to sign non-disclosure agreements with a small businessman who comes to the PNGV program in order to determine the worth to the program of a new technology he or she wanted to advance?
If not, why not?

a.) Is this a standard procedure that the government follows in its negotiations?

A. Initially, the Partnership would prefer to evaluate new technologies without the bureaucratic delays inherent in non-disclosure agreements. Small businesses are encouraged to protect information through patents and other traditional mechanisms consistent with established business practices. If a technology appears to have promise, it is typically in the best interest of both the supplier and the Partnership to enter into non-disclosure agreements.

QUESTIONS FROM CONGRESSWOMAN JACKSON LEE

1Q. The structure and management of the program have been called into question by some people. Can you give me recommendations as to how the program could be restructured on the government or industry side to bring about better or more efficient management?

A. The management structure of PNGV was agreed upon by our companies and our partners in the Federal agencies recognizing the realities of agency management within existing program budgets, as well as the need for large competing companies to work together on pre-competitive research. We all understand that this management structure is somewhat tedious in that it must rely on consensus building rather than command and control. But just as no Federal agency or Congressional committee will cede control of its budget to another, it is even less appropriate for a corporation to cede control of future products to a competitor's project manager. We have continued to improve efficiency within the present structure by sharing pre-competitive technology and combining industry/government research programs whenever possible. The shared-responsibility management system that we are using is familiar to anyone who has worked with risk-sharing joint ventures. While cumbersome at times, this consensus style of operation leads to frank dialog about issues and potential solutions and produces high-quality decisions.

2Q. When do you see the technologies being developed under the PNGV program coming into wide use in the production of automobiles?

A. The industry has committed to offer new technologies developed in PNGV on conventional vehicles as soon as they become commercially viable. This process has already begun with the introduction of both composite and aluminum parts (such as hoods and trunk lids) to replace conventional steel applications for weight reduction. As the technical development process continues, more and more applications are expected to benefit all classes of vehicles leading to more efficient vehicle fleets that offer increased payload or increased fuel efficiency options to the public.

3Q. Can you tell me what the returns are that we can expect from the PNGV program in terms of reduced oil usage, new car exports and environmental benefits?

A. PNGV is a research program that has very ambitious goals. The positive contributions of the program will be directly related to the degree that we achieve our objectives and the acceptance of this new class of highly sophisticated vehicles by the public. It is difficult to identify specific timetables and deliverables for PNGV benefits, however, we believe that development of these technologies would have widespread societal benefits and contribute to air quality, energy security, and improved industrial competitiveness.

4Q. Although it's early yet, at this point in the program, which goals do you see in danger of the program not meeting?

A. In the words of the NRC Peer Review Panel, "Despite progress, there is still a wide gulf between the current status of major vehicle systems and subsystems and the performance and cost requirements necessary to meet major PNGV milestones... Some of the technical barriers to achieving PNGV objectives can probably be overcome with sufficient technical breakthroughs."

We are awaiting critical data from ongoing studies in several technologies that will help to answer your question. Although we are optimistic that the partnership will dedicate sufficient resources to support the research goals, there are significant technical barriers to be addressed in every candidate technology, particularly with regard to breakthrough fuel-efficiency technologies.

USCAR RESPONSE TO REPRESENTATIVE WAMP

Q. Does use of lighter weight materials in vehicles to reduce mass compromise safety?

A. The PNGV goal is to achieve up to three times improvement in fuel efficiency without compromising customer acceptability of the product, including affordability and safety. The specifics of our technical strategy include up to a 40% weight savings for the total vehicle. Our objective is to achieve the PNGV technical targets, including the weight savings, without compromising safety, performance or other customer expectations and needs.

This is a significant challenge. The connection between occupant safety and vehicle weight and size has been thoroughly examined over the years and is well understood for the current materials and designs used in cars and light trucks. A number of studies have been done by government and private sector organizations that have clearly demonstrated that reducing either vehicle size or weight will reduce occupant safety. This safety impact has been a major concern of the auto companies when responding to regulatory requirements such as higher fuel economy standards for vehicles, which may require automakers to reduce vehicle size and/or mass.

The PNGV program expects to avoid one of these problems by not undertaking any significant downsizing in the vehicles. Maintaining vehicle size will maintain the crush space of existing vehicles and thus will not reduce the space in the PNGV vehicles in which the energy of the crash must be managed.

Just as important as size, however, is the mass (or weight) of the vehicle. In most accident situations, the occupants of the vehicles involved are better protected when their vehicles have more mass. According to the basic laws of physics, heavier vehicles have an advantage in deforming or displacing obstacles such as trees, poles, and fences. This allows these vehicles valuable additional space to decelerate the vehicle and its occupants. Statistical evidence shows that these safety advantages afforded to occupants of heavier vehicles more than outweigh any disadvantages, such as increased risk to pedestrians or bicyclists. Thus, PNGV's goal of reducing weight by 40% without adversely affecting safety is a substantial task.

New steel, aluminum, and composite materials will be used to accomplish the weight savings. A key criterion in material selection and design will be the properties that these materials display in vehicles. Aluminum and composites have shown the potential to be superior energy absorbers compared with current materials.

Vehicle structural designs and enhanced occupant restraint systems are expected to be the primary tools for achieving today's equivalent crash protection performance with lighter weight materials.

In summary, reducing mass generally involves reducing vehicle safety, but it is hoped that maintaining size and crush space while incorporating new advanced materials and safety technologies will allow PNGV to increase fuel efficiency by up to three times without sacrificing safety.

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

QUESTIONS FOLLOWING THE HEARING ON

Partnership for a New Generation of Vehicles (PNGV):
Assessment of Program Goals, Activities and Priorities

HELD ON

Tuesday, July 30, 1996
1:00 p.m. - 4:00 p.m.
2318 Rayburn House Office Building

Responses to Questions Submitted
to NRC on August 8, 1996

SUBMITTED BY

Trevor O. Jones, Chairman
NRC-PNGV Standing Committee

Q1) Your testimony and review seems to be constrained and measured. Would a Congressionally-mandated annual review allow you a less constrained response?

A1) a. The testimony may have seemed constrained and measured to the Subcommittee. However, this was totally due to the extremely short time (5 to 7 minutes) given to present the findings of a very broad and complex program. The two reports of the NRC Committee are quite specific with regard to its evaluation of the PNGV program and its recommendations. I would be pleased to provide a more extensive presentation of the reviews to the Subcommittee.

b. A Congressionally-mandated annual review would not result in a less constrained response.

Q2) In its second annual report, the NRC PNGV Standing Committee states: "progress has been made toward Goals 1 and 2 [of the PNGV] since the first NRC review in August 1994". You do not comment on the level of progress on these two goals. You also state in your testimony (p.5), ".. there is significantly less risk associated with Goals 1 and 2 compared to Goal 3." What level of participation by the federal government is now justifiable in Goals 1 and 2?

A2) It is not possible to comment on a justifiable level of federal government participation in the absence of definitive and measurable objectives for Goals 1 & 2.

Q3) Will the PNGV program be able to meet all of the technical requirements needed for the 1997 milestone of selecting the most promising technologies? If not, what should be done to optimally address that?

A3) a. It is unlikely that all of the technical requirements needed for the 1997 milestone of selecting the most promising technologies will be met. This aspect of the PNGV program will be a major topic of the NRC's third review starting on September 9, 1996.

b. The timely selection of the most appropriate technologies could be enhanced by increasing and/or redistributing funds to the critical areas indicated in the Second NRC report issued March, 1996.

Q4) You rate the potential, "regardless of schedule", for success of the fuel cell option as *Medium*. Please describe the barriers that lead to this conclusion. Could a stronger commitment by the PNGV to development of fuel cells result in a more speedy resolution of these barriers?

A4) a. The challenges faced for fuel cell system development are clearly set out in the PNGV Technical Roadmap, which lists them as: "...cost, efficiency...unattended reliability and durability." In addition it states, "PNGV cost and efficiency targets are the major challenges for fuel processing, while cost and energy density targets are the major challenges for hydrogen storage." System targets set forth in the Technical Roadmap include a peak power efficiency of 53 percent, compared with an estimate of 45 percent today; and a power density of 0.4 kW/l, and specific power of 0.4 kW/kg, both of which are about twice the estimated state of the art today. It is important to note that the efficiencies quoted above are based on the use of hydrogen as a fuel[1]. Since it is unlikely that hydrogen can be stored on board a vehicle under the constraints established by PNGV Goal 3, vehicle efficiency calculations based on fuel sources may be more appropriate.

The cost reduction target is by far the most challenging--from over $200 per kW today to $30 per kW (in 1995 dollars) by 2004. Hydrogen storage targets of 2 kWh/l and 3 kWh/kg can only be approached with costly and energy-inefficient liquid storage systems. Today, such storage of gaseous hydrogen would require five times the PNGV target size and 2.7 times the target weight, as specified in the Technical Roadmap. The committee did not receive estimates for the current size and weight of fuel processors for converting hydrocarbon or methanol fuel to hydrogen on board the vehicle, but targets of 0.5 kW/l and 1.0 kW/kg have been established by the PNGV.

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[1] Efficiencies of overall systems, including a reformer, are frequently not known and also depend on the reformer fuel. The use of an efficiency based on hydrogen is helpful as a standard and for comparison purposes.

A4) b. It is more appropriate to maintain adequate funding on a sustainable basis within a well-defined and managed program than to seek speedy resolutions of barriers because inventions and breakthroughs are required.

The NRC's third review of the PNGV program will specifically address this subject.

Q5) Gas turbines, direct injection compression ignition, DICI (direct injection diesel) and fuel cell are identified as the three primary energy converters. Despite the technical and cost issues remaining with the development of gas turbines for automobiles and the lack of solutions for particulate and NOx emissions from the Diesel option, the Committee does not take very clear and strong positions on these three options. Are other options available that were not considered due to lack of interest by the PNGV organization?

A5) a. Very clear opinions on the energy conversion options are presented in the NRC report, namely:

DICI (Page 50 of the Second NRC Report)

"In the committee's view, a variable geometry turbocharged, direct-injected, variable-swirl, compression-ignition engine with a unique lightweight structure, complex high-pressure fuel system, using sophisticated electronic controls and exhaust after treatment should not in any way be considered "conventional." It currently is the most promising alternative to achieve the goals of the PNGV program within the prescribed time frame."

Gas Turbine (Page 51 of the Second NRC Report)

"The pursuit of ceramic materials for high-temperature turbomachinery has a long history and has yielded advances in the knowledge base. Indeed, many millions of dollars have been spent over many years in this area in support of automotive and military projects, especially in the United States. Unfortunately, in spite of this sizable effort, no satisfactory materials or fabrication techniques have been found that could extend to the type, size, and cost requirements of engines suitable for the PNGV application. Specifically, the material technology is expensive, even for the raw materials alone. Also, the process of forming them into the proper shapes is costly. There are problems in reducing the ceramic components to the size required, while still meeting the essential performance criteria (e.g., for strength, durability, and precision).

Gas turbine engines face a major cost hurdle to achieve the PNGV goal. Historically, high-speed, high-temperature turbomachinery has been more costly than less compact, heavier powerplants. The need for precision ceramic components may render the cost target difficult to achieve within the PNGV time schedule."

A5) Fuel Cells (Page 55 of the Second NRC Report)

> "Fuel cells, in the long term, offer the potential of high-energy conversion efficiency. Cost remains a major problem. Mass production alone is not enough to drive the cost of today's state-of-the-art fuel cell systems down to acceptable levels. No satisfactory fuel supply solution is apparent, although some candidates have certain attractive features. Hydrogen infrastructure and storage concerns force consideration of using on board fuel processors, which, in turn, substantially compromise the efficiency advantage of the fuel cell. As noted above, substantial progress is being made, but several major research breakthroughs are still needed for this technology to meet PNGV technical targets and schedules."

b. The NRC Committee is not aware of any other options that it has not considered.

Q6) Neither the PNGV plan nor your assessment of the DICI technology addresses the need to develop appropriate fuels for this particular approach. Are you aware of any efforts to find appropriate fuels for DICI and perhaps solve some of the pollution problems with reformulation of the fuel?

A6) a. The PNGV was beginning to consider the issues surrounding fuel requirements and the possible benefits of reformulated fuel at the time of the second NRC Committee review. These studies were in their early stages are referred to in the Committee's second report under Recommendation 4 in the Powertrain Section, page 60, as follows:

> **Recommendation.** The PNGV should perform a study to establish the energy balance, in-use environmental effects, and resource requirements, as well as production and distribution costs, for any fuels other than gasoline or diesel fuel being considered for use in Goal 3 vehicles.

Dimethyl ether, referred to on page 63 of the report, is a fuel being considered as having potential to reduce both particulate and NOx emissions.

b. The Second NRC Report alerted the PNGV program of the need to study the infrastructure implications of candidate technologies. The following paragraph is extracted from Chapter 7 Infrastructure of the NRC-PNGV report:

"The adoption of alternative PNGV power plants that use fuels such as methanol, dimethyl ether or hydrogen would create immense demands on the entire fuel production, transportation, storage, and retail-distribution infrastructure. Significant new investments would be required both in the production and retail segments. Portions of existing facilities and equipment could become obsolete, resulting in the early writeoff of investments. The willingness of consumers to adapt to the use of alternative fuels will also have an important influence on the success of the PNGV program.

> The highway infrastructure includes the highway system, the vehicle and its operator, and the services associated with vehicle operation. The operation of vehicles producers the undesirable consequences of property damage, human casualties, and environmentally harmful emissions. A number of significant issues relating to PNGV arise from highway infrastructure considerations."

The subject of infrastructure and environmental impact will become a critical consideration during technology downselect in late 1997. PNGV's proposed solutions will be evaluated by the NRC Committee at that time.

Q7) You note a lack of participation by DOT, EPA and DOD in the PNGV program. Is this due to a lack of interest by the agencies or a lack of encouragement by the PNGV?

A7) It is my understanding that these agencies have been invited to participate in PNGV. It would be more appropriate to ask this question of the individual agencies.

Q8) What are the impacts of the electric vehicle developments on the PNGV and vice versa?

- a) Has the U.S. prompted a competition by the European and Asian countries by announcing the PNGV?
- b) What kind of competition are we facing now?

A8)
- a. Since the PNGV vehicle will most probably be hybrid-electric, there is considerable synergy with electric vehicle developments and vice versa.
- b. The existence of the PNGV program has prompted active programs in Japan and Europe. On a crude technology assessment basis, each nation or group of nations has its strengths and weaknesses. In my view, the largest international competitive threat would come from a competing nation that enters the market with a PNGV-type vehicle at something less than 80mpg -- perhaps 50 - 60 mpg.

Q9) Can an effective system analysis of PNGV concept vehicles be performed without having selected the technologies, or are you using system analysis as a "design/system performance evaluation tool" to assist in selection of the appropriate technologies?

- a) Why has this particular activity been delayed in the PNGV program?

A9)
- a. The details surrounding the delay in initiating the systems analysis subcontract should be provided by the PNGV.
- b. Yes; it is mandatory that systems analysis be used in the selection of technologies to be applied to PNGV vehicles.

c. Comprehensive and rigorous systems analysis would provide engineers and scientists with the basic comparative data to select the optimum components, subsystems and systems.

RESPONSES TO QUESTIONS FROM CONGRESSWOMAN JACKSON LEE

Q1) The structure and management of the program have been called into question by some people. Can you give me any recommendations as to how the program could be restructured on the government or industry side to bring about better or more efficient management?

A1) The following recommendations on program management are taken from Page 79 of the second NRC report issued in March, 1996:

Recommendation. The committee still strongly recommends that the partners in USCAR appoint a single technical director as a way of benefitting from the leverage of an integrated organization in pursuit of PNGV goals.

Recommendation. The committee reiterates its earlier recommendation that senior management at DOC and DOE install a management structure with appropriate authority and responsibility as soon as possible and ensure strong, capable staffing. This structure should include a chief technical officer to provide technical direction to the wide array of government technical activities. The role of the chief technical officer becomes even more critical in the absence of a single USCAR technical program director.

Recommendation. To be successful, a complex development program such as PNGV must have well-defined plans and objectives, adequate resources, and the support of sufficient funding. It is incumbent upon both USCAR and the government to ensure that adequate resources for the PNGV program are provided in a timely manner and used efficiently in overcoming the critical barriers to achieving PNGV goals.

Q2) When do you see the technologies being developed under the PNGV program coming into wide use in the production of automobiles?

A2) This question can be more fully responded to following technology selection at the end of 1997. For those Goal 3 technologies which are selected, it will be at least a decade from now before they are in wide use in production automobiles.

Q3) Can you tell me what the returns are that we can expect from the PNGV program in terms of reduced oil usage, new car exports and environmental benefits?

A3) If the PNGV program comes close to meeting its technological, cost, and timing goals, it could launch the automotive industry in a new era of global competitive achievement, resulting in substantial improvements in the quality of life for all Americans. The benefits of the program are potentially far reaching in terms of a strong industrial base, fuel savings, reduced carbon dioxide emissions, less air pollution, and lower oil imports. The benefits will, however, accrue over a long period of time and will be widely distributed.

Q4) Although it's early yet, at this point in the program, which goals do you see in danger of the program not meeting?

A4) PNGV has set extremely aggressive performance, cost and schedule goals and as such, it is unlikely that all of the goals will be met simultaneously by the year 2004.

Since the goals are extremely tough, any shortfall should not cause the program to be considered a failure. In my opinion, the achievement of a x2 fuel economy and higher would be an outstanding. Achieving the x3 fuel economy would be remarkable.

The largest single challenge is to achieve the specified performance levels within the defined production cost goals. To date, no technology has demonstrated this combined capability (cost and performance), hence, the need for a concentrated and adequately funded long-term R&D program.

RESPONSES TO QUESTION FROM CONGRESSMAN ZACK WAMP

Q1) Does use of lightweight material in building [automobiles] compromise [their] safety?

A1) The use of lightweight materials in vehicles need not compromise safety provided adequate care is taken in the structural design of the vehicle to effectively manage crash energy during impact conditions.

A larger issue is the relative safety of lighter weight vehicles when co-mingled with larger and significantly heavier vehicles on the highway.

Subcommittee on Energy and Environment
Committee on Science
U.S. House of Representatives

Questions Following the Hearing on:

Partnership for a New Generation of Vehicles (PNGV): Assessment of Program Goals, Activities and Priorities

Held on

Tuesday, July 30, 1996
1:00 p.m. - 4:00 p.m.
2318 Rayburn House Office Building

Responses by Dr. Robert Hirsch, Member, NRC-PNGV Standing Committee to Questions Submitted to NRC on August 8, 1996

Q1. You stated in your testimony that: "A major issue of concern to our review committee is the level of funding for the government part of the PNGV program. The PNGV program plan included estimates of required government funding levels, which were to grow over time. The levels were considered essential to program success...." How were these considered to be essential?

A1. Without adequate funding, not enough work will be done to make informed decisions on the PNGV program schedule currently envisioned. The choices are then to either delay the decision making in order to accumulate the needed information over a longer period of time or to make a decision with available information, thereby increasing the risk of not achieving the program objectives. There is no question that the reduced funding levels and reduced participation by the government since the PNGV program was initaited has decreased the likelihood that the program will succeed in its goals, particularly Goal 3 of achieving up to 80 mile per gallon production prototype vehicle by the year 2004. However, it is entirely possible that the current program with its reduced funding will lead to a 50 or 60 mpg vehicle, which would still be a considerable accomplishment.

Q2. Do you continue to recommend that a single technical director for USCAR be named? (a) Does the fact that each of the three car companies is pursuing different concept vehicles have any bearing on this recommendation?

A2. The PNGV committee recommended a single technical director for USCAR in both of its reports. During the preparation of the second report, the committee was aware of the decision by the three car companies to develop separate concept vehicles and production prototypes, and we still recommended a single technical director.

Q3. In light of your recommendation to establish “a management structure with appropriate authority and responsibility,” and the fact that all the technical issues relevant to Goals 2 and 3 of the PNGV and difficult decisions facing the partnership at the 1997 milestone fall within the activities of DOE, what future role do you see for the DOC management?

A3. I assume that the 1997 decisions will be the result of the whole government-industry management team deliberating and expressing their various views. The most important decisions will be made by the three car companies, because they will be making choices on which they will be investing significant levels of their own corporate resources. In that regard, none of the government personnel involved will be a major decision maker. On the other hand, in light of the 1997 decisions, the government managers will have to decide which projects to cut back or eliminate in order to free up the funding needed to more vigorously pursue the selected technologies. That will be a difficult task in light of the various pressures to continue existing projects.

Revised 10/31/96

September 9, 1996

To: Ms. Jennifer Disharoon, Staff Assistant
Subcommittee on Energy and Environment
Committee on Science
B-374 Rayburn House Office Building
Washington, D.C. 20515

From: Daniel Sperling, Professor and Director
Institute of Transportation Studies
University of California, Davis
Davis, CA 95616

RE: Responses to questions from the Subcommittee, and from Congresswoman Jackson Lee, from the July 30 PNGV hearing.

QUESTIONS FROM THE SUBCOMMITTEE FOR PROF. DANIEL SPERLING

1. There seems to be a reluctance by the PNGV program to pursue the higher risk technologies such as fuel cells and hydrogen-fueled Auxiliary Power Units (APUs), when one of the key justifications for the industry/government partnership is development of high-to-medium risk technologies. Can you please comment on that?

The PNGV program as currently structured does not strongly encourage, and may soon be discouraging, investments in higher risk technologies such as fuel cells. The root of this problem is the required 1997 "downselect" process of the PNGV program. By downselecting to only one technology (or set of technologies) in such a short time, PNGV obliges the 3 automakers to pick those technologies that are less risky -- those more likely to be successfully deployed in a prototype in 2004. The companies have little reason to be more adventurous, since there are no penalties for falling short of the 80 mpg goal. Possible solutions are: i) require that a specified % of automaker matching funds and government funds be spent on long term higher-risk technologies; ii) delay the "downselect" date a year or two to allow more progress on advanced technologies; and /or iii) create an enforcement mechanism or penalties so that companies have more motivation to meet the 80 mpg goal.

2. Do you believe that there is adequate involvement by small businesses and universities in the PNGV program? Are there mechanisms that allow such involvement and protection of innovative concepts proposed by small companies and research universities? If not, can you suggest improvements?

I strongly believe that there is not enough involvement by universities. There is virtually no opportunity for universities to get involved in PNGV activities, nor with any DOE advanced vehicle technology R&D programs, unless they are affiliated with the 3 automakers. The National Science Foundation provides some funds for PNGV-type research, but the programs are too diffuse and small to be effective in building advanced vehicle technology research programs at universities. There are virtually no major university research programs devoted to fuel cells and other advanced technologies. The result is that universities are not training the next generation of automotive engineers, and regulators and policymakers lack a means to assess the rate of progress of Big 3 R&D and advanced technology commercialization efforts.

The situation with small businesses is different. Many small businesses *are* involved in PNGV, but virtually always through an affiliation with the Big 3 and their key suppliers. This approach has strong advantages -- small companies develop close relationships with the customers for their technology -- but it also means that, again, policymakers and regulators lose a means of benchmarking automaker progress, and it also means that the tempo of commercialization is controlled by the automakers.

It should be noted here that concerns about the tempo of commercialization are somewhat unique to the PNGV program. Generally, competition between companies is sufficiently intense to assure that innovation will be stimulated and new technologies will be rapidly commercialized; in those cases, government need only seed long term basic research, and then get out of the way of industry. PNGV is unique in that most of the benefits of the technologies are "public goods" -- that is, the benefits accrue to the nation as a whole, and not directly to individual consumers. And thus, tempo of commercialization *is* critical, with government facing the special challenge of directing companies to serve the public interest, even though it may not be in their immediate interests.

3. Are the goals and milestones of the PNGV reasonable? If not, please comment.

The goals and milestones of PNGV seem reasonable, though the downselection date should be delayed, or a parallel program implemented to support the more advanced technologies.

4. ***Do you believe that the PNGV organization is pursuing all potential technologies to achieve the best solution to the problem posed by Goal 3?***

I believe that PNGV has been thorough in evaluating the menu of technologies available. They are making hard judgments about which technologies are most promising. It may have been inappropriate and ill-advised to ignore pure battery-powered electric cars -- PNGV did so by creating performance criteria that can not be met by pure EVs -- but the PNGV program is using technology developed for pure EVs as building blocks for hybrid and fuel cell vehicles.

5. DOE, NRC Review and many others seem to indicate that fuel cells as a power plant for automobiles are more than 10 years away. Do you agree or disagree with that assessment, and what do you see as the role of government in such long-term research areas?

Fuel cells provide huge promise for improved fuel efficiency and reduced air pollution and greenhouse gas emissions. Dramatic improvements in cost and performance have been made in the past few years with fuel cells. There is still a long way to go. It is impossible to know how long and how far rapid cost and performance improvements will continue, but there appears to be no fundamental engineering or scientific reason why they should not continue. Daimler Benz believes that fuel cells may be ready for commercialization in 10 years. If government makes certain that automakers are strongly rewarded for selling cars with superior environmental performance, and consumers for buying them, then the economics and competitiveness of fuel cell vehicles are greatly enhanced. The potential benefits are so great, that it would be irresponsible not to aggressively pursue fuel cell technology. Government R&D funding levels do not acknowledge the potential economic and environmental potential of fuel cells; they reflect the scientific and political realities of 5 years ago, before the promise of fuel cells was fully appreciated.

6. Do you believe that the PNGV program is aggressively addressing the technical issues brought on by its Goal 3?

No, I do not believe that PNGV is aggressively addressing the technical issues brought on by its goal 3. See my responses to earlier questions for elaboration.

QUESTIONS FROM CONGRESSWOMAN JACKSON LEE

1. The structure and management of the program have been called into question by some people. Can you give me recommendations as to how the program could be restructured on the government or industry side to bring about better or more efficient management?

As indicated in the NRC review, PNGV seems to have little or no ability to redeploy funds from less significant to more important technology developments in response to budget reductions or following technology selection. A central cause of this problem seems to be that DOE, which provides and controls over 95% of the funds for Goal 3 (tripled fuel economy) and virtually all the technical expertise in this area, does not have control of that part of the PNGV program. To improve efficiency, it would be sensible for DOE to be given full responsibility for Goal 3 activities.

2. When do you see the technologies being developed under the PNGV program coming into wide use in the production of automobiles?

Many of the advanced technologies considered under the PNGV umbrella are already being implemented -- consider, for instance, the many innovations imbedded in GM's EV1 electric car. The challenge for government is to create a regulatory and policy environment that rewards industry for selling environmentally superior technology, and customers for buying them.

3. Can you tell me what the returns are that we can expect from the PNGV program in terms of reduced oil usage, new car exports and environment benefits?

The auto industry is on the cusp of a technological revolution: dramatic improvements are being made in lightweight materials, energy storage and conversion, and electronic control and information management. The PNGV program is highlighting many of these technologies and bringing them to public attention. With appropriate policies and regulations, oil usage and environmental impacts could be drastically reduced. These benefits will take time to be realized because of slow vehicle turnover in the marketplace and long lead times in retooling factories, but the longer we delay in initiating the development and commercialization of these advanced technologies, the longer it will be before we realize the benefits.

The more immediate impact of hybrid and fuel cell vehicles is likely to be on balance of trade. These new technologies are likely to be attractive to many other countries -- those with severe air pollution, high oil import bills, and entrepreneurial industrial companies that want to expand their automotive production efforts. US automakers could exploit the desire in these various countries for more efficient and environmentally benign technologies (as well as in the US), or could passively defer to more aggressive foreign companies. By allowing other countries take the lead they forego opportunities to make inroads in foreign markets and risk losing market share in the US.

4. Although it's early yet, at this point in the program, which goals do you see in danger of the program not meeting?

Given the current absence of incentives for achieving 80 mpg, as well as penalties for *not* achieving it (much less achieving improvements beyond 27.5 mpg), and given the stifling effect of the 1997 downselect rule, it appears highly unlikely that the 80 mpg goal will be achieved.

Appendix III

Statement of Dr. Jay O. Keller
Hydrogen Program Manager
Sandia National Laboratories

United States House of Representatives
Committee on Science
Subcommittee on Energy and Environment

Hearing on
Partnership For A New Generation Of Vehicles (PNGV):
Assessment of Program Goals, Activities, and Priorities

July 30, 1996

Introduction

Mr. Chairman and distinguished members of the subcommittee, I am Jay Keller, hydrogen program manager at Sandia National Laboratories. Sandia is managed and operated for the Department of Energy by a subsidiary of Lockheed Martin Corporation. We perform scientific and engineering research and technology development in support of DOE's missions in nuclear weapons and arms control, energy, environment, and the basic sciences.

I appreciate this opportunity to share with you my assessment of the state of hydrogen technology development and how hydrogen might play a role in the Partnership for a New Generation of Vehicles (PNGV) program.

The Department of Energy has established capabilities at Sandia National Laboratories to address complex issues in hydrogen utilization. These capabilities include, but are not limited to, hydrogen storage and advanced materials expertise, associated with the nuclear weapons program for over 40 years; fundamental combustion expertise at the Combustion Research Facility, a DOE user facility supported by the office of Energy Research for over 20 years; and internal combustion engine expertise developed through the Office of Transportation Technologies over 20 years. I manage Sandia's hydrogen program and coordinate hydrogen utilization activities for the Department of Energy.

Let me begin by explaining the motivation for developing hydrogen as a principal energy carrier generated by renewable energy sources. I will then discuss how a combination of the activities of PNGV and those of the national hydrogen program provides a unique opportunity to demonstrate hydrogen as a future transportation fuel.

Why Hydrogen?

There are two motivating reasons for developing a hydrogen infrastructure: 1) hydrogen will be a key fuel in future sustainable energy systems that will rely on renewable energy resources; 2) hydrogen energy systems have minimal environmental impacts. Chronic dependence on foreign oil is a national security issue, and the continued combustion of hydrocarbon fuels degrades the environment. The rapid growth of emerging industrial economies (most notably China) will increase pressure on our finite, fossil-derived energy resources and shorten the time horizon over which we need to respond. The development of a hydrogen energy infrastructure, with the long-term goal of using renewable energy sources to produce hydrogen domestically, addresses these issues.

Technology Options

A long-term, stable solution to our energy and environmental problem requires development of a global energy infrastructure based on environmentally benign renewable energy sources. Energy storage and distribution are key infrastructural requirements to implementing this solution. Renewable energy sources are often intermittent and are more plentiful in some areas than others (for example, solar energy is only available during the day). Renewable energy requires a means for both energy storage and transportation. Hydrogen, generated from renewable sources, provides an ideal medium for energy storage and transportation. When combined with oxygen, it forms water and releases energy. Hydrogen is a gas at normal temperatures and pressures and can be transported in much the same way as natural gas.

Converting the energy of stored hydrogen into useful work can be accomplished by many technologies. The most attractive long-term technology for this purpose is the fuel cell. Fuel cells combine hydrogen and oxygen, without combustion, to produce water and electricity. Proton Exchange Membrane (PEM) fuel cells are devices that the transportation sector finds most attractive for many reasons. They operate at modest temperatures with potentially very high efficiencies and they emit only water; thus, PEM fuel cells satisfy the California zero-emission requirement. The DOE Office of Transportation Technologies, in collaboration with automobile manufacturers and other industries, is supporting the development of PEM fuel cells for use in the transportation sector. Two foreign companies have already created prototype vehicles powered by PEM fuel cells: Mercedes in Germany has an operational minivan, and Ballard in Canada has a bus.

Conventional internal combustion engines can also be made to operate on hydrogen. Mazda, Daimler-Benz, and most notably BMW have all built prototype passenger vehicles demonstrating the feasibility of conventional internal combustion engines burning hydrogen. MAN, a major European bus manufacturer, has constructed a hydrogen-powered bus from a standard production city bus with an internal combustion engine designed to operate on either hydrogen or gasoline. Both the hydrogen and gasoline are stored in liquid form. This particular bus has been in service since April, 1996. MAN has orders for 100 hydrogen-fueled buses for Norway and 50 for Sweden.

Most recently, BMW displayed two of the latest versions of their hydrogen-powered vehicles at the 11th World Hydrogen Conference in Stuttgart, Germany (June 21–29, 1996). These vehicles are powered by spark-ignited internal combustion engines with electronic fuel injectors designed to operate on hydrogen. One cannot distinguish this engine from a conventional gasoline fueled engine without very careful inspection. The hydrogen is stored as liquid in a tank immediately behind the passenger seat in the trunk of the vehicle, leaving plenty of trunk space for other uses. Sufficient hydrogen is stored to provide about a 300 kilometer range. These vehicles cannot easily be distinguished from gasoline-powered production models either in appearance or performance. (There is a modest power loss due to the excess combustion air needed to reduce nitric oxide emissions.) Indeed, the fuel metering technology works for gasoline as well as hydrogen, making the vehicle dual-fueled. The fuel type can be changed during operation by the flick of a switch.

Although hydrogen vehicles have been demonstrated, we face formidable R&D challenges in implementing large-scale hydrogen-based transportation systems. Specialized materials for hydrogen storage must be developed to assure adequate vehicle range. Advanced fuel cells and internal combustion engines are required for ultra-low emission, high-efficiency vehicles. Hydrogen production and distribution systems must be designed that are safe and cost-effective.

A Domestic Opportunity

PNGV has identified three research goals: 1) design and manufacturing; 2) near-term improvements; and 3) long-term, next-generation vehicle. Goal 3 parameters are: 1) a six-passenger vehicle (similar to Taurus, Lumina, or Concorde); 2) three-times fuel efficiency or about 80 m.p.g. equivalent performance on the combined city/highway, unadjusted federal test procedure; 3) performance of 0 to 62 m.p.h. in 12 seconds; 4) operating metro-highway range of 380 miles on the 1994 federal drive cycle and operating life of 100,000 miles; and 5) equivalence to current vehicles in performance, ride, handling, noise, vibration, and so forth. Customer features include: interior volume, luggage space, climate control, etc., as well as customer purchase price and operating economics.

Goal 3 of the PNGV program provides an opportunity to combine the goals of the hydrogen program with those of PNGV to introduce hydrogen as a transportation fuel of the future. Hybrid vehicles are being pursued as part of the technology mix to address Goal 3. All hybrid vehicles require an energy conversion device to convert stored chemical energy from the onboard fuel to usable energy to power the vehicle. These devices can range from internal combustion engines powered on conventional hydrocarbon fuels to PEM fuel cells powered on hydrogen. All of these are being considered by the PNGV program.

An additional technology for hydrogen utilization employs a hydrogen-fueled internal combustion engine as the energy conversion device in a PNGV-type hybrid vehicle. This vehicle can be constructed today. Our efforts in the hydrogen-fueled internal combustion engine program focus on this opportunity. In this design, an electrical generator is combined with a hydrogen engine tuned to operate at maximum efficiency with minimal emissions. With continued research and development we anticipate significant improvements over the current state of the art in both engine emissions and efficiency because of the unique combustion characteristics of hydrogen. Current laboratory results show that a total efficiency of 40% (hydrogen in, electricity out) may be achievable. This efficiency is comparable to that of today's PEM fuel cells. Using results obtained from our laboratory engine and assuming conservative hybrid vehicle performance, we project emission levels of oxides of nitrogen lower than the equivalent zero emission standard proposed by the California Air Resources Board and lower than those demonstrated by BMW.

Given their similar goals and closely related technological approaches, the hydrogen and PNGV programs taken together provide an opportunity to begin the introduction of an energy infrastructure using sustainable energy resources with hydrogen as the energy carrier. Other countries have already begun to position themselves for the move to a hydrogen-based energy economy. Through the hydrogen and PNGV programs, the United States has an opportunity to establish a predominant international position in hydrogen-fueled vehicle technologies.

REVIEW OF THE RESEARCH PROGRAM OF THE PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

SECOND REPORT

Standing Committee to Review the Research Program of the
Partnership for a New Generation of Vehicles

Board on Energy and Environmental Systems
Commission on Engineering and Technical Systems
Transportation Research Board
National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

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Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles

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ACRONYMS

AISI	American Iron and Steel Institute
ATP	Advanced Technology Program
CRADA	cooperative research and development agreement
CVT	continuously variable transmission
DICI	direct-injection, compression-ignition
DOC	U.S. Department of Commerce
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
FY	fiscal year
GFRP	graphite fiber-reinforced polymer
HEV	hybrid electric vehicle
ITS	Intelligent Transportation System
LEP	Low Emission Partnership
NASA	National Aeronautics and Space Administration
NSF	National Science Foundation
NRC	National Research Council
OEM	original equipment manufacturer
OTA	Office of Technology Assessment
PEM	proton exchange membrane
PNGV	Partnership for a New Generation of Vehicles
R&D	research and development
SRIM	structural resin-injection-molding
TACOM	Tank Automotive Command
ULEV	ultra-low emission vehicle
USCAR	United States Council for Automotive Research
WWW	World Wide Web

Contents

HIGHLIGHTS 1

1 SUMMARY 5
Introduction, 5
PNGV Response to the Phase 1 Report, 7
Goals 1 and 2, 7
Major Technical Barriers and Achievements, 8
Systems Analysis, 15
Foreign Technology, 16
Program Organization and Management, 17
Infrastructure, 19
Participation by Government Agencies, 20
National Commitment, 20
Funding Requirements, 21
Timely Correction of Program Deficiencies, 21
Peer Reviews of the PNGV, 22
References, 22

2 INTRODUCTION 23
References, 26

3 PNGV RESPONSE TO PHASE 1 REPORT 27
References, 29

4 GOALS 1 AND 2 30
Goal 1, 30
Goal 2, 32
Issues, 33

5 STRUCTURAL MATERIALS 34
The PNGV Approach, 34
Materials Options, 35
Issues, 38
Recommendations, 39
References, 40

6 POWERTRAIN DEVELOPMENTS 41
Powertrain Technologies Being Studied, 41
Key Technology Summaries, 44

Likelihood of Meeting Goal 3 Powertrain Needs, 52
Recommendations, 53
References, 53

7 INFRASTRUCTURE 55
Infrastructure Implications of PNGV Technologies, 55
Safety, 56
PNGV Activities, 57
Issues, 57
Recommendations, 58
References, 58

8 SYSTEMS ANALYSIS 60
Recommendations, 62

9 PROGRAM ORGANIZATION AND MANAGEMENT 63
PNGV Technical Roadmap, 63
Technical Organization Structure, 64
Schedule and Resources, 66
Program Management, 67
Foreign Technology, 68
Peer Reviews of the PNGV, 69
Recommendations, 70
References, 70

10 NATIONAL COMMITMENT 71

APPENDICES

A Biographical Sketches 77
B Committee Meetings and Activities 85
C PNGV Response to the Phase 1 Report and Supporting Documentation 89
D United States Council for Automotive Research Consortia 98
E PNGV Position Regarding Electric Vehicles 104

List of Tables and Figures

TABLES

H–1 Potential of PNGV Candidate Technologies, 3
1–1 Preliminary Ranking of U.S., European, and Japanese Advanced Automotive Technologies, 17
5–1 Vehicle Mass Reduction Targets for PNGV Goal 3 Vehicle, 36
9–1 Preliminary Ranking of U.S., European, and Japanese Advanced Automotive Technologies, 69

FIGURES

5–1 PNGV Design Space, 35
9–1 PNGV Technical Organizational Structure, 65

Highlights

This is the second report of the National Research Council's Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles (PNGV). The PNGV program is a cooperative research and development (R&D) program between the federal government and the United States Council for Automotive Research (USCAR). One of the aims of the program, referred to as the PNGV Goal 3 objective, is to develop technologies for a new generation of vehicles that could achieve fuel economies up to three times those of comparable 1994 family sedans. At the same time, these vehicles should maintain performance, size, utility, and cost of ownership and operation and should meet or exceed federal safety and emissions requirements. The intent of the program is to develop production prototype vehicles by 2004. The next major PNGV milestone, scheduled for 1997, is selection of the most promising technologies. The committee's major tasks were to examine ongoing research activities in the PNGV and to assess the relevance of that research and its management to the PNGV's goals and schedule.

Most of the PNGV research to date has focused on improving drivetrain efficiency, developing improved energy storage systems, and reducing vehicle mass through the use of lightweight structural materials. In the committee's view, the technologies being pursued are relevant and appropriate to the PNGV objectives, and significant achievements have been made. Nonetheless, formidable technical barriers remain to meeting the program goals within the PNGV schedule. Some of these barriers can be overcome with sufficient resources; others will require a new invention or a major technical breakthrough.

Three primary energy converters or power sources are being actively considered for PNGV Goal 3 vehicles; namely, direct-injection compression-ignition (DICI) internal-combustion engines, fuel cells, and gas turbine engines. The DICI engine shows promise of being highly efficient, although the development of appropriate catalysts to reduce NO_x exhaust emissions remains a significant barrier. The committee recommends that the PNGV devote substantial additional resources to the DICI hybrid powertrain in view of its relatively high potential to meet PNGV Goal 3 objectives.

From the standpoint of automotive applications, fuel cells offer the potential for high efficiency and low emissions. However, fuel cells are the least developed option under consideration for a power source, and they present the most barriers to a commercially viable system. Despite a number of significant PNGV achievements in fuel-cell technology, fuel-related barriers remain. Several major inventions are needed for the successful development of hydrogen storage systems or efficient, compact fuel processors for hydrocarbon fuels. Although fuel cells have outstanding long-term potential, the PNGV may find it necessary to restructure the fuel-cell program, extending the schedule and revising funding priorities, depending on progress over the next two years.

Gas turbine engines have many potential advantages for hybrid vehicles, including very high specific power, but the main barriers continue to be the difficulty of increasing thermal efficiency and finding satisfactory materials and manufacturing techniques to achieve the necessary performance at acceptable cost. The research challenges for gas turbine engines are very demanding, but the PNGV has made some progress. In the committee's view, the pace of progress over the next two years will be a critical determinant of whether the gas turbine engine remains a viable PNGV option.

Energy storage systems recapture otherwise wasted vehicle kinetic energy and reduce peak load requirements for the main propulsion system, thereby increasing operating efficiency. Current PNGV support is concentrated on three candidates—batteries, flywheels, and ultracapacitors. Although substantial progress has been made in virtually all areas of battery technology critical to battery hybrid vehicles, present high-power batteries cannot simultaneously satisfy the power density, energy density, and cycle-life requirements for the PNGV energy-storage subsystem. Therefore, a combined battery/ultracapacitor subsystem is under consideration. The performance of ultracapacitors has shown significant improvement in laboratory demonstrations, with increased energy and power densities, but major barriers remain with respect to total energy storage and cost. The cost of power electronics is a barrier to the integration of all power components, including batteries, ultracapacitors, and flywheels. R&D on flywheels has resulted in significant performance improvements; but cost remains a barrier, and safety concerns need to be addressed.

Goal 3 vehicles will make significant use of lightweight structural materials. Notable PNGV achievements in this area include the demonstration of high-volume fabrication processes for steel and aluminum. The committee recommends that USCAR continue to pursue these very promising developments in steel and aluminum materials made by materials suppliers and trade associations. Despite some progress, the composites program is lagging with no clearly scheduled activities that would enable this class of materials to be viable alternatives to steel and aluminum by 1997.

An approximate assessment of the broad potential for major PNGV candidate subsystems is presented in table H-1. The committee made a distinction between systems for which technical breakthroughs are needed to meet PNGV targets and those for which incremental development with adequate resources (funding and staff) is likely to lead to the necessary progress. The committee has identified the most critical barriers to meeting PNGV performance requirements, as well as the approximate cost and the likelihood of meeting PNGV schedules. These three factors have been used to derive a first approximation of the overall potential regardless of the PNGV schedule and to further highlight program priorities. The committee recommends that the PNGV perform appropriate evaluations to ensure that its program resources and focus are, in general, consistent with the "basic needs" column of table H-1. If necessary, program funding should be reallocated to encourage developments.

TABLE H-1 Potential of PNGV Candidate Technologies

Major Subsystems	Critical Technical Barriers	Cost[a]	Likelihood of Meeting Schedule[a]	Overall Potential Regardless of Schedule[b]	Basic Needs
Hybrid Drivetrain Power Sources					
DICI	NO_x catalyst	Low	High	High	Resources
Fuel cell	Fuel processor/ reformer Fuel storage	High	Low	Medium	Breakthroughs
Turbine	Structural ceramics Exhaust heat recovery	High	Low	Medium	Breakthroughs
Energy Storage					
Battery	High cycle life	Medium	Medium	Medium	Resources, focused R&D
Ultracapacitor	Efficiency Self-discharge Safety	Medium	Medium	Medium	Breakthroughs, resources
Battery/ ultracapacitor	Integration Safety	Medium	Medium	High	Breakthroughs, resources
Flywheel	Safety	High	Medium	Medium	Resources, focused R&D
Power electronics	Efficiency	High	High	High	Resources
Lightweight Structural Materials					
Composite	High-volume manufacture Crashworthiness	High	Low	Medium	Resources, focused R&D
Aluminum	High-volume manufacture Joining	Medium	High	High	Focused R&D
Steel	Weight	Low	Medium	Medium	Focused R&D

[a] High cost is a barrier, as is low likelihood of meeting the PNGV schedule.

[b] Long-term potential beyond 2004.

In addition to the Goal 3 objective, the PNGV program also aims to significantly improve national competitiveness in manufacturing (Goal 1) and implement commercially viable innovation from ongoing research on conventional vehicles (Goal 2). The committee observed that progress has been made towards Goals 1 and 2 since the first NRC review in August 1994.

Despite significant improvements in program organization in the past year and the resulting technical achievements, the committee concluded that the USCAR members are not using the leverage of an integrated industry organization in pursuit of PNGV goals. The committee continues to believe strongly that the industry partners would be well served by having a single technical program director in USCAR to drive and coordinate the program. The committee also noted that the government lacks an effective program management organization, with little or no ability to redeploy funds from less significant to more important technology developments in response to budget reductions or following technology selection. The committee considers strong program management on the government side to be essential to the success of the program, given the large number of government participants.

Systems analysis in the PNGV program is critical to the successful development of components, systems, and overall vehicle design. However, very little has been accomplished in this area because of a lack of funding and a resulting 12- to 18-month delay in initiating the systems analysis activity. The committee concluded that the PNGV does not currently have the necessary systems analysis tools to adequately support the technology selection scheduled for 1997. This deficiency constitutes a barrier to meeting the PNGV program goals in a timely manner. A further concern is that contributions from the National Aeronautics and Space Administration for the systems analysis work are uncertain beyond fiscal year 1996. The committee was also concerned that the U.S. Department of Transportation is not playing an active role in addressing and resolving PNGV transportation policy and safety issues and that the U.S. Environmental Protection Agency does not appear to be addressing the question of emissions standards for new PNGV technologies. The U.S. Department of Defense also needs to be more supportive and involved in the PNGV research program.

To be successful, a complex development program such as the PNGV must have well-defined plans and objectives, adequate resources, and sufficient funding support. Although significant progress has been made, in the committee's view, it is incumbent upon both USCAR and the government to ensure that adequate resources for the PNGV program are provided in a timely manner and used efficiently in overcoming the critical barriers to achieving PNGV goals.

1

Summary

INTRODUCTION

This is the second report of the National Research Council's (NRC) Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles (PNGV). The committee was established in July 1994 to conduct independent reviews of the PNGV's research program. To date, two reviews have been undertaken at the request of the U.S. Department of Commerce (DOC). The PNGV program is a cooperative research and development program between the federal government and the United States Council for Automotive Research (USCAR), which comprises Chrysler Corporation, Ford Motor Company, and General Motors Corporation. The decade-long program, which was initiated on September 29, 1993, by President Clinton, has three major goals:

1. Significantly improve national competitiveness in manufacturing.
2. Implement commercially viable innovation from ongoing research on conventional vehicles.
3. Develop a vehicle to achieve up to three times the fuel efficiency of today's comparable vehicles, while maintaining or improving current levels of performance, size, utility, and total cost of ownership and while meeting or exceeding federal safety and emissions requirements.

For this second review, the committee was charged with performing the following tasks:

- Assess the progress of the PNGV program since August 1994 and the PNGV response to recommendations of the first NRC review.
- Examine ongoing research activities in the PNGV.
- Assess the relevance of that ongoing research and its management to the PNGV's goals and schedule.
- Prepare a second peer review report.

In fulfilling the assigned tasks, the committee took as given the vision, goals, and schedules for the PNGV program that were articulated by the President and agreed to by USCAR in September 1993. The committee also operated under the premise that the program would be seriously supported and pursued by the government and industry partners. Given the lack of quantitative objectives for Goals 1 and 2, as well as the time constraints on conducting the second peer review, the committee chose to focus on activities relating to Goal 3. The current absence of quantitative objectives for Goals 1 and 2 complicates any assessment of progress toward these goals.

This report is based on presentations made to the committee by the PNGV (i.e., by representatives of industry and the government, including the national laboratories) on August 27-31, 1995, in Dearborn, Michigan, and on October 30-31, 1995, in Washington, D.C. These presentations were supplemented by committee member site visits to the engineering development facilities of the USCAR partners (see appendix B). Some of the material was presented to the committee as USCAR proprietary information under an agreement signed by the National Academy of Sciences; USCAR; and the U.S. government, represented by DOC. At the meeting in Washington, D.C., on October 30-31, 1995, the committee also received briefings from U.S. and overseas organizations outside the present PNGV. The information presented allowed the committee to assess the status of various PNGV technology developments from a broad, international perspective.

The PNGV concept is to bring together the extensive research and development resources of the federal establishment, including its national laboratories and network of university-based research institutions, and the vehicle design, manufacturing, and marketing capabilities of both the USCAR partners and suppliers to the automotive industry. Government funding for the PNGV will primarily be used for technology developments that involve high risk (Goal 3 and beyond). USCAR funding will be used mainly to develop technologies with clear, near-term market potential (Goals 1 and 2).

The PNGV program was launched just over two years ago, in September 1993. The first major program milestone is scheduled for 1997, when the PNGV must select technologies for the concept vehicles that will be designed, developed, and fabricated by 2000. The technical challenges are daunting, and, as discussed herein, inventions and breakthroughs are needed before certain technologies can be considered as viable options for selection in 1997. At present the PNGV is diligently pursuing research and development (R&D) programs focused on specified technical targets; however, major breakthroughs and inventions are difficult to anticipate. For this reason, the committee has not explicitly called for the PNGV to separate likely technologies into "winners and losers" at this time. The committee concluded that classifying technologies in this way would be premature prior to 1997, when ongoing research that provides data for technology selection has been completed.

The committee's major recommendations, including its position on the PNGV response to the Phase 1 report, are presented in this chapter. Additional recommendations are also given in individual chapters of the report.

PNGV RESPONSE TO THE PHASE 1 REPORT

In its earlier report, issued after the first review of the PNGV research program, the committee offered a number of recommendations for the PNGV's consideration (NRC, 1994). These recommendations are provided in appendix C. Progress, changes in the original program, and material presented to the committee during the current review indicate that the PNGV has resolved many of the issues raised in the Phase 1 report. These issues include:

- development of a technology strategy, as outlined in the PNGV Technical Roadmap (PNGV, 1995)—a document that is still evolving and is subject to revisions
- involvement of suppliers, notably in the development of improved materials and manufacturing processes
- preliminary benchmarking of technology developments abroad
- enhancement of public outreach, primarily through a media education program and the PNGV home page on the World Wide Web

However, the PNGV has yet to address other important issues in a substantive way. Outstanding items of particular concern to the committee are the following:

- the need for a USCAR-PNGV technical director
- the need for more support and involvement in the PNGV research program by the U.S. Department of Transportation (DOT), the U.S. Department of Defense (DOD), and the National Aeronautics and Space Administration (NASA)
- the need to analyze technologies in current and post-PNGV categories[1] and to consider appropriate plans and schedules for further development

GOALS 1 AND 2

As stated previously, the committee chose to focus on activities relating to Goal 3. However, information provided to the committee on research relating to Goals 1 and 2 indicates that progress has been made in these areas, notably under USCAR consortia (appendix D) and Cooperative Research and Development Agreements (CRADAs) with the national laboratories. This progress in manufacturing processes is extremely important, and its continuation may be a major factor in determining the viability of several Goal 3 technologies. In general, achievements in the Goal 1 and Goal 2 programs will form an important base on which to build and against which to compare Goal 3 technologies.

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[1] Current PNGV technologies would include all technologies that have a high probability of demonstrating PNGV system applicability and performance by 1997. Post-PNGV technologies would have a high probability of meeting PNGV goals but not within the current time frame (NRC, 1994).

MAJOR TECHNICAL BARRIERS AND ACHIEVEMENTS

From the outset of the PNGV program it was widely accepted that achieving the challenging fuel economy target of Goal 3 would require implementation of new concepts and technologies, some of which are revolutionary relative to the level of technology in conventional vehicles (PNGV, 1995). Two recent reports on automotive fuel economy also highlight the limitations of current automotive technologies and indicate that new concepts and technologies will be required to meet demanding fuel economy targets (OTA, 1991; NRC, 1992). Preliminary studies by PNGV provided an overview of the performance improvements necessary in major vehicle systems to obtain the 80-mpg equivalent fuel economy; tradeoffs were identified between increasing drivetrain efficiency, reducing vehicle mass, and increasing storage of deceleration energy, along with projected improvements in aerodynamics, rolling resistance, and accessory power requirements. Although the PNGV has performed only limited systems analysis of fully integrated vehicle options, several conceptual vehicle configurations were identified that may have the potential to meet Goal 3 basic vehicle performance requirements. It appears that the leading contenders will be various hybrid electric vehicles.

Most of the technical efforts to date have focused on improving drivetrain efficiency, developing improved energy-storage systems, and reducing vehicle mass through the use of lightweight structural materials. A number of significant achievements have been made, although there are still formidable barriers to meeting the program goals within the PNGV schedule. These barriers are reflected in the PNGV assessment of the status of R&D aimed at meeting Goal 3 technical targets. Fundamental technical barriers and deficiences in resources were also clearly identified by Sloane (1995).

The next major PNGV milestone is narrowing the focus of the program in 1997 by selecting the most promising technologies. In the light of recent technical progress (see below) and the fact that only two years of the ten-year program have elapsed, the committee considers it extremely important that the PNGV be given the opportunity, and flexibility in its research agenda over the next two years, to pursue appropriate developments that could lead to breakthroughs essential for making informed decisions in 1997. However, in assessing the relevance of ongoing research to the PNGV program goals and schedule, the committee identified a number of technical barriers that may affect the 1997 selection process. The committee made a distinction between technical barriers that can be overcome with sufficient resources and technical barriers that can only be overcome with a new invention or a major technical breakthrough. Both types of barrier exist in the PNGV program. The former type can probably be overcome through the allocation of sufficient resources and management attention; however, the latter type of barrier requires inventions or breakthroughs, and barriers of this type create a much higher risk that performance objectives will not be met or completed within the PNGV's schedule.

The committee observed that, given the limitations on existing resources, the technology program must be more focused if PNGV performance, cost, and schedule objectives are to be met. The committee recommends that program funding be reassessed and reallocated in a way consistent with encouraging development breakthroughs but without terminating any of the technology development programs prior to the scheduled 1997 selection process. The following comments are intended to provide guidance for the PNGV in activities leading to a successful technology selection in 1997.

Drivetrain Power Sources

Three primary energy converters or power sources are actively being considered for PNGV Goal 3 vehicles: direct-injection, compression-ignition (DICI) internal-combustion engines, gas turbine engines;[2] and fuel cells. All of these will operate as hybrids. The further development of spark-ignited internal-combustion engines is being pursued as part of Goal 2.

Direct-Injection, Compression-Ignition Engines

The DICI engine shows promise of being highly efficient and is arguably the frontrunner of the power-source candidates at this time. Two points are noteworthy in this regard:

1. The DICI engine being considered is very different from traditional passenger car diesels and faces many significant technical challenges. The DICI engine, operating in a hybrid configuration, is currently the most promising candidate for fulfilling the PNGV goals within the specified schedule.
2. Commercialization of an advanced DICI engine will be highly dependent on the ultimate exhaust emission standards that are promulgated. If the standards become more stringent than those for the current ultra low emission vehicle, DICI engines could be eliminated from the marketplace.

It is the committee's understanding that little or no significant research is being performed on DICI automotive engines in the United States, except for investigations of lean-burn NO_x reduction and fuel reformulation. In contrast, in Europe and Asia, where automotive DICI engines using diesel fuel are more widespread and more highly developed, continuing efforts are underway to further improve DICI engine technology. Some of this work is being performed by the European units of U.S. car companies. The committee concludes that substantial resources should be applied immediately to DICI development to redress an imbalance in the PNGV program in accordance with current projections of technology potential.

There have been significant achievements in combining industry and government laboratory efforts to develop commercially viable advanced catalytic converters, notably the Engine Support System Technology program within the USCAR Low Emission Partnership.

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[2] Gas turbine does not refer to the type of fuel but rather to the type of power plant, as opposed to "steam" turbine or "cold air" turbine.

While substantial reductions in NO_x exhaust emissions have been achieved in the steady-state, the development of an acceptable lean NO_x catalyst for DICI engines remains a significant barrier. Given the progress made in this area in the past two years and the extremely high value of lean NO_x catalysts, the committee believes an aggressive, PNGV-funded, DICI exhaust emission control program, potentially capable of overcoming this barrier, should be initiated.

Fuel Cells

From the standpoint of automotive applications, fuel cells are the least developed option under consideration for a power source. Not surprisingly, therefore, fuel cells present the most barriers to a commercially viable system. There have been a number of significant PNGV achievements in fuel cell technology, including recent rapid improvements in stack design for optimizing thermal, water, and fuel management and substantial progress in improving membrane performance. Projected costs have also been reduced. Stack power density has been doubled to about 1.0 kW/l (the PNGV 1997 technical target); potentially low-cost bipolar plates have been successfully built and tested; and a prototype methanol reformer has been successfully demonstrated for a 10 kW proton exchange membrane (PEM) system.

Despite this progress, fuel-related barriers remain. There is as yet no satisfactory method of storing sufficient quantities of hydrogen for hydrogen-powered vehicles onboard, and reformers do not meet acceptable cost, size, and performance requirements for storing hydrocarbon fuels in hydrocarbon-powered fuel cell vehicles. Other barriers include the development of components for ancillary systems (e.g., air conditioning, power steering, etc.) with improved performance and reduced size and weight, further cost reductions in all areas, and a reduction in startup time.

Some barriers can probably be overcome with increased, focused R&D. However, several major inventions are needed for the successful development of hydrogen storage systems and efficient, compact fuel processors for hydrocarbon fuels. Order-of-magnitude cost reductions are also unlikely without significant breakthroughs. These observations are consistent with recent estimates suggesting that a fuel cell drivetrain will require 10 to 15 years of development before it can be mass produced efficiently and within the needed cost range (Klaiber, 1995). In keeping with the outstanding long-term potential of fuel cell technology, the committee strongly supports the continued development of automotive fuel cells. Depending on progress over the next two years, the PNGV may find it necessary to restructure the fuel cell program, extending the schedule and revising funding priorities.

Gas Turbine Engines

Gas turbine engines have many potential advantages for hybrid vehicles; notably, very high specific power, minimal vibration, no cooling system other than for oil, and the ability to operate on a wide variety of fuels. The main barriers continue to be lowering the costs to acceptable levels and increasing thermal efficiency.

The thermal efficiency gains needed to meet PNGV goals depend on developments in three technical areas: raising turbine inlet temperatures; recovering a significant amount of waste heat; and increasing component efficiencies. Raising turbine inlet temperatures requires appropriate high-temperature materials. In this context, the successful 1,000-hr rig test of ceramic vanes and rotor blades represents a major PNGV achievement. However, the development of a low-cost, robust manufacturing technique capable of producing structural ceramic components with the necessary strength, toughness, and durability remains a major challenge. Further, there are problems with the aerodynamic design and manufacture of small, high-efficiency compressors and turbines, especially when using ceramic materials. Significant progress has been made in developing heat recovery systems, but barriers remain to reducing the size, weight, and cost of the heat exchangers, as well as to developing desirable seal materials.

Advances have been made in system definition, including the completion of turbo-alternator designs. Barriers that need to be addressed include further reducing NO_x levels, developing more efficient high-speed generator/alternators, reducing packaging volume, and significantly reducing costs.

The research challenges for gas turbines are very demanding, but the PNGV has made some progress in each area of development. In the committee's view, the pace of progress over the next two years will be a critical determinant of whether the gas turbine engine remains a viable PNGV option.

Energy Storage

Energy-storage systems capable of high-rate charge and discharge are fundamental to hybrid electric vehicles. They recapture otherwise wasted vehicle kinetic energy and reduce peak load requirements for the main propulsion system; thus, operating efficiency is increased. Current PNGV support is concentrated on three energy-storage systems—batteries, flywheels, and ultracapacitors.

Battery technologies being investigated include lead-acid, nickel-cadmium, nickel-metal hydride, lithium-ion, lithium-polymer, sodium-sulfur, and zinc-air. The two lithium cells offer promise in terms of both energy and power density and low material costs. However, there are barriers to be overcome in developing cost-effective manufacturing processes; achieving high cycle life, which is dependent on stable electrode morphology; and producing the very thin, large-area plates needed for high power output. Barriers to the use of nickel-cadmium and nickel-metal hydride batteries include high costs.

Substantial progress has been made in virtually all areas of battery technology critical to battery-hybrid vehicles. However, at present, the high-power battery technologies under consideration cannot simultaneously satisfy the power-density, energy-density, and cycle-life requirements for the PNGV energy-storage subsystem, and a combined battery/ultracapacitor subsystem is under consideration (PNGV, 1995). The performance of ultracapacitors has shown significant improvement in laboratory demonstrations, with energy and power densities up to 10 Wh/kg and 2 kW/kg, respectively; greater than 90 percent turnaround efficiency; and greater than 100,000 cycles. Major barriers remain with respect to total energy storage, which is currently limited to less than about 2 kWh, and costs, which must be reduced by about two orders of magnitude to meet PNGV requirements. There are other cost issues associated with integrating batteries and ultracapacitors; notably, the need for expensive power electronics. For ultracapacitors, there are also barriers to be overcome with respect to self-discharge rates and, possibly, safety, in the case of non-uniform cell discharge.

R&D on flywheels has resulted in significant improvements in energy density, reductions in self-discharge, and limited demonstration of containment in compact structures following catastrophic failure (rotor burst). Major barriers remain in the areas of cost and safety. The price of the materials must be reduced by approximately one order of magnitude, and satisfactory mass manufacturing techniques must be developed before the flywheel system can be cost competitive. With respect to safety, it is not clear that a satisfactory solution has been found to the problem of burst containment. It may be that avoidance of catastrophic burst—rather than burst containment—is necessary for industry and public acceptance. Other, less formidable barriers include electrical turnaround efficiency, the high-cost of interface power electronics, determination of possible gyroscopic effects from shock loading, and development of a companion high-speed, high-efficiency motor/generator.

Lightweight Structural Materials

Meeting Goal 3 objectives depends on major improvements in both drivetrain efficiency and reduced vehicle mass. Goal 3 can only be achieved with significant use of lightweight structural materials. Important achievements have been made in identifying and prioritizing developments in materials technology, organizing investigation teams, and effectively communicating the PNGV requirements to the materials supplier community.

Advances in the development of lightweight structural materials have resulted in notable technical achievements applicable to meeting all three PNGV goals. Topics investigated by the PNGV included more efficient use of steel, primarily through improved manufacturing processes; the extensive use of aluminum for body structure, with emphasis on low-cost fabrication methods; and the extensive use of polymer-based composites for body closures and structures.

PNGV achievements of note include the demonstration of a high-volume, structural resin-injection-molding composite process for underbody crossmembers; the fabrication of slab and belt cast aluminum sheets in automotive alloys; and the demonstration of significant progress in resolving forming, joining, and painting issues for new, high-volume applications of aluminum closure panels. The PNGV has also been able to exert its substantial leverage to stimulate investment in research and development by materials suppliers in the United States without recourse to government funding.

Major barriers for the development of lightweight, low-cost materials for body structures and closures remain. These include the production of continuous slab castings of aluminum sheet and the formulation of recyclable composites that have the necessary structural properties (including crashworthiness) and very short processing times. The committee anticipates that these barriers can be overcome if investigations are appropriately focused and resources are applied by effective, integrated USCAR teams.

Summary of Achievements

The committee concluded that the PNGV has made significant technical progress since the Phase 1 peer review, notably in the following areas:

- development of a catalyst demonstrating substantial reductions in NO_x exhaust emissions
- satisfactory completion of a 1,000 hr-rig test of ceramic vanes and blades for gas turbine engines
- improvements in fuel cell performance, including the doubling of stack power denisity, and the design and testing of a potentially low-cost bipolar plate
- demonstration of high-volume fabrication processes for lightweight materials
- improvements in the performance of high-power batteries, ultracapacitors, and flywheels

Summary of Technical Barriers

Despite progress, there is still a wide gulf between the current status of major vehicle systems and subsystems and the performance and cost requirements necessary to meet major PNGV milestones.[3] Some of the technical barriers to achieving PNGV objectives can probably be overcome with sufficient funding and management attention; others require inventions and very significant technical breakthroughs.

The effort currently being expended on candidate technologies and systems is not consistent with the likelihood that each will meet performance goals within the program schedule. Work on some critical systems is inadequately funded, lacks integrated technical direction, or does not adequately leverage relevant activities being conducted within some government agencies.

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[3] These milestones include technology selection in 1997, design and construction of concept vehicles by 2000, and the availability of production prototypes in 2004.

The assessment of technical barriers to the development of major candidate PNGV subsystems presented in this report was used as a basis for constructing table H-1 (see Highlights). In the committee's view this table provides a summary and an approximate assessment of the broad potential for candidate PNGV elements. The committee made a distinction between systems for which technical breakthroughs are needed to meet PNGV targets and those for which incremental development with adequate resources (funding and staff) is likely to lead to the necessary progress. For each major subsystem, the committee identified the most critical barriers to meeting PNGV performance requirements, as well as the approximate cost and the likelihood of meeting PNGV schedules. These three factors were used to derive a first approximation of the overall PNGV potential regardless of the PNGV schedule and to further highlight program priorities.

For example, overcoming the barriers to composite materials meeting the PNGV performance requirements for lightweight body structure will require significant further development but can probably be successful with sufficient time and effort. However, the likelihood of meeting PNGV requirements within the specified timeframe is low, and the cost of composites is high when compared with the cost of steel or aluminum. Thus, the overall PNGV potential for composite materials is rated medium, indicating that significant resources will be required to take advantage of the promise of composite materials for use in automobiles. In contrast, it is not apparent that the barriers for gas turbines meeting PNGV targets can be overcome without major breakthroughs, even with additional resources. Despite significant R&D effort over the past 20 years—and some limited successes—there is currently no robust, low-cost manufacturing process for producing high-temperature structural ceramics that have the necessary combination of strength and toughness for use in automobiles.

Another approach to assessing the potential of candidate technologies is presented in a recent report from the Office of Technology Assessment (OTA), which attempts to answer the question, "What happens to a mid-size car in 2005 and 2015?" (OTA, 1995). OTA was generally optimistic about the potential of advanced vehicle technologies providing excellent vehicle performance. However, the OTA was more cautious about the speed with which technologies can be made commercially available and introduced widely into the market. In general, the committee does not take issue with the major findings of the OTA report.

Recommendations

With regard to technology barriers, the committee recommends the following:

Recommendation. PNGV should perform appropriate evaluations to ensure that its program resources and focus are, in general, consistent with the "Basic Needs" column of table H-1. If necessary, program funding should be reallocated to encourage developments.

Recommendation. PNGV should devote substantial additional resources to the DICI hybrid powertrain in view of its relatively high potential to meet Goal 3 objectives.

Recommendation. PNGV should focus ultracapacitor R&D on the most promising technologies, and serious efforts should be devoted to the investigation of a battery/ultracapacitor hybrid storage system.

Recommendation. On a standalone basis, batteries still appear to be the best near-term candidates for energy storage, and PNGV should fund development of the most promising battery systems consistent with this potential.

Recommendation. PNGV should continue to develop flywheel and generator technologies.

Recommendation. USCAR should continue to use the process it has developed—incorporating its substantial leverage through integrated industry programs—to pursue the very promising developments in steel and aluminum materials made by materials suppliers and trade associations. The development of innovative manufacturing processes for aluminum and steel should be encouraged and accelerated.

SYSTEMS ANALYSIS

Systems analysis in the PNGV program is critical to the successful development of components, systems, and overall vehicle design. Systems analysis provides the analytical capability to efficiently and accurately assess competing technologies and vehicle concepts against Goal 3 vehicle performance requirements (PNGV, 1995). Systems analysis studies are also essential to provide component designers with performance targets and reasonable tradeoff parameters. The PNGV has established technical teams for systems analysis and vehicle engineering and a preliminary overall plan; however, very little has been accomplished because of a lack of funding. A contractor for developing appropriate system, subsystem, and component models was recently selected, but there was a 12- to 18-month delay in initiating this critical PNGV systems activity. The impact of the delay on the program, and particularly on the technology selection scheduled for 1997, is currently unclear. The absence of, or deficiencies in, systems support for subsystem and component tradeoffs could compromise the effective selection of optimal technologies for the design, fabrication, and assembly of concept vehicles. It would help accelerate the systems analysis activity and make up for lost time if the USCAR partners provided PNGV with their in-house systems models to the extent appropriate.

The committee concludes that the PNGV does not currently have the necessary systems analysis tools to adequately support the technology selection scheduled for 1997. This deficiency constitutes a barrier to meeting the PNGV program goals on time. The PNGV must assess the extent to which this barrier can be overcome without delay and must allocate appropriate resources to correct the deficiencies.

Recommendations

With regard to systems analysis, the committee recommends the following:

> **Recommendation**. The PNGV should assess the impact on the overall program schedule of the delay in implementing systems analysis and vehicle engineering tasks, and the need for remedial action. Priority projects must be identified and implemented by the technical teams as soon as possible.
>
> **Recommendation**. The PNGV should formalize subsystem evaluation and selection process without delay and provide performance criteria to the PNGV technology teams. The systems analysis must be an iterative process that continually receives new information, updates models, and provides updated results from optimizations and tradeoff studies to system, subsystem, and component designers.

FOREIGN TECHNOLOGY

In its Phase 1 report, the committee noted that it would be appropriate for the PNGV to more fully evaluate applicable technology developments outside the United States. Consistent with this observation, the committee received briefings (see appendix B) and reviewed articles on foreign automotive technology programs to assess the competitive status of the PNGV program from a broad, international perspective. Active government-industry partnerships in Europe and Japan—somewhat analogous to the PNGV initiative—are pursuing the development of advanced automotive technologies to maintain or enhance their international competitiveness. The committee noted that there is likely to be fierce international competition to produce highly efficient vehicles for sale on a global basis.

A very preliminary ranking of foreign automotive technology development compared with technology development within the PNGV is presented in table 1-1. This assessment is based on preliminary, limited information presented to the committee by the PNGV (Hardy, 1995). The rankings shown in table 1-1 are judgmental. Nonetheless, they suggest that, compared with its major overseas competitors, the United States is not in a clear leadership position in developing critical technologies for PNGV-type vehicles. It should be noted, however, that automotive companies in Asia and Europe are not necessarily targeting the same vehicle as the PNGV, and they may have different marketing strategies.

Recommendation

With regard to foreign technology, the committee recommends the following:

Recommendation. As a matter of urgency and in accordance with the committee's recommendation in its first report, the PNGV should conduct more comprehensive assessments and benchmark foreign technology developments relevant to the program. If warranted by the results of such analyses, PNGV should reassess its research priorities.

TABLE 1-1 Preliminary Ranking of U.S., European, and Japanese Advanced Automotive Technologies

Technology	U.S.	Europe	Japan
Internal combustion, compression ignition engine	3	1	2
Internal combustion, spark-ignition engine	2	2	1
Gas turbine	1 (systems)	1 (systems)	1 (components)
Fuel cell	Immature technology—no ratings assigned		
Flywheel	1	1	3
Battery	1 (high energy)	2	1 (high-power)
Ultracapacitor	3	3	1
Lightweight materials	2	1 (aluminum)	1 (high-strength steel)

Note: 1 = highest ranking; 3 = lowest ranking

PROGRAM ORGANIZATION AND MANAGEMENT

The committee noted that the PNGV Technical Roadmap, developed since the Phase 1 review, does a good job of describing the major technologies being pursued, the target performance levels, and the schedule.[4] The committee assumed that some missing details in the roadmap (identifying resource requirements and some quantitative performance measures) would be added by the PNGV in future revisions. During the past year, the PNGV has also solidified its technical organization structure, which centers on the technical teams responsible for manufacturing, materials and structures, and systems analysis. Technical oversight and coordination are provided by the vehicle engineering team. These teams appear to be organized effectively and are working toward specific objectives, although the committee was concerned that some key management personnel from USCAR spend only a very limited amount of time on PNGV activities. The committee also observed that the process for program review against specific targets and milestones in the technology development plan was not clearly defined. More specifically, the technology selection process scheduled for 1997 has not been established, despite the fact that this major milestone is less than two years away. This may be due, in part, to the very late start of the formal systems analysis.

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[4] It is the committee's understanding that these technical targets are preliminary and subject to change as progress is made in the PNGV R&D program.

PNGV program planning, organization, and management have been influenced by a recent decision by Chrysler, Ford, and General Motors not to develop a single USCAR concept car. Each company will now pursue its own concept car (or cars), sharing PNGV and USCAR information as appropriate. The committee noted that this change puts an added premium on good communications among the USCAR partners, as well as between USCAR and government participants in the PNGV, to ensure that there is close coordination between the work of the PNGV technical teams and the needs of the individual automotive manufacturers and that government-sponsored projects have the greatest opportunity of providing the essential technology to meet unified performance requirements. Since the PNGV will not build a concept car, the coordination of PNGV systems analysis and vehicle engineering efforts requires strong, central management control. This could be provided by a single USCAR technical director.

Despite significant improvements in program organization in the past year and the resulting technical achievements, the committee concluded that the USCAR members are not using the leverage of an integrated industry organization in pursuit of PNGV program goals. In the committee's view, the absence of an integrated working group has had an adverse impact on the program. This lack of integration is reflected in the decision of Chrysler, Ford and General Motors to develop individual concept vehicles, the delay in starting the systems analysis, and the limited amount of time spent on USCAR business by some key management personnel. The committee continues to believe strongly that the industry partners would be well served by having a single technical program director in USCAR to drive and coordinate the program, as was recommended in the Phase 1 report.

The committee observed that the government also lacks an effective program management organization. The program management office at the DOC essentially operates as an information office. Program managers at DOC and the U.S. Department of Energy (DOE) are not empowered to direct the array of federal PNGV projects that contribute to and are essential to the PNGV initiative. In particular, PNGV management on the government side has little or no ability to redeploy funds from less significant to more important projects in response to budget reductions or following technology selection. The committee considers strong central program management on the government side to be essential to the success of the program, particularly in the absence of a single USCAR technical program director.

The committee noted that, despite the above deficiencies in program organization and management, personnel from the diverse cultures of government and industry are working together effectively while fully embracing the goals of the PNGV, as was the case during the Phase I review. In the committee's judgment, the working relationships that have developed in the PNGV are commendable.

Recommendations

With regard to program organization and management, the committee recommends the following:

> **Recommendation**. The committee still strongly recommends that the partners in USCAR appoint a single technical program director as a way of benefitting from the leverage of an integrated organization in pursuit of PNGV goals.
>
> **Recommendation**. The committee reiterates its earlier recommendation that senior management at DOC and DOE install a management structure with appropriate authority and responsibility as soon as possible and ensure strong, capable staffing. This structure should include a Chief Technical Officer to provide technical direction to the wide array of government technical activities. The role of the Chief Technical Officer is even more critical in the absence of a single USCAR technical program director.

INFRASTRUCTURE

Some of the technologies under consideration for the PNGV vehicle would, if implemented, result in very significant changes in the current highway-vehicle-fuel infrastructure, as well as shifts in the requirements for capital, labor, and natural resources. Thus, in the absence of detailed analysis, it is not clear that all scenarios being considered would meet the objectives of increasing competitiveness, reducing dependency on foreign energy sources, and lowering energy consumption. In particular, modifications to the current vehicle infrastructure associated with changes in safety criteria, automotive service industries, fuel use, and vehicle-operator interactions have important implications for market acceptance of a PNGV-type vehicle.

A preliminary study of infrastructure issues for the PNGV was completed during the past year by a research team from Argonne National Laboratory (Johnson, 1995); the committee commends the PNGV for taking this first step. The committee sees a continuing need to address infrastructure issues as an integral part of the PNGV program. In particular, careful assessment of infrastructure issues associated with alternative technologies should be an essential part of the selection process scheduled for 1997.

The use of lightweight materials, energy-storage and conversion systems, and alternative fuels will raise numerous safety issues. New vehicle designs, which pose new safety questions, will need to be at least as safe as conventional vehicles. The absence of active participation by DOT in addressing and resolving PNGV safety issues is seen by the committee as a major deficiency in the current program.

Recommendations

With regard to infrastructure, the committee recommends the following:

Recommendation. The PNGV must continue to address infrastructure issues as an integral part of its program. A careful assessment of infrastructure issues associated with alternative technologies should be an essential part of the technology selection process scheduled for 1997.

Recommendation. The PNGV should perform a study to establish the energy balance, in-use environmental effects, and resource requirements, as well as the production and distribution costs, for any fuels other than gasoline or diesel fuel being considered for use in Goal 3 vehicles.

Recommendation. The PNGV should immediately involve the DOT's National Highway Traffic Safety Administration, in identifying, addressing, and resolving the safety issues raised by Goal 3 vehicles.

PARTICIPATION BY GOVERNMENT AGENCIES

The DOE is the largest participant in the PNGV program in terms of research projects, followed by the National Science Foundation. The other partners are the DOC, DOD, DOT and NASA, as well as the U.S. Department of the Interior and the U.S. Environmental Protection Agency. The committee noted that a visible commitment, as well as increased participation by all the partners, are essential to the success of the PNGV program. The fact that DOT has decided on a "zero" contribution to PNGV in fiscal year (FY) 1996 and that NASA's contribution to the systems analysis work are uncertain beyond FY 1996 suggests a lack of commitment to the program within the administration. The committee was particularly concerned that (1) DOT is not playing an active role in addressing and resolving PNGV transportation policy and safety issues, and (2) the Environmental Protection Agency does not appear to be addressing the question of emissions standards for new PNGV technologies.

NATIONAL COMMITMENT

Given the ambitious scope of the PNGV program and its decade-long schedule, sustained commitment is needed for success. Significant benefits can be anticipated from the program; notably, in economic competitiveness, increased national security, and improved environmental quality. These benefits will, however, accrue over a long period of time and be widely distributed. For these reasons it is unlikely that any group of constituents will be drawn to develop and sustain support for the program. Therefore, the PNGV has an important role to play in providing and disseminating information about the program.

The PNGV program office has made significant progress in this regard in the past year, primarily through a media education effort and the establishment of a World Wide Web site on the Internet. Opportunities may exist for the PNGV to further enhance the effectiveness of its media education effort by instituting strong coordination among the public affairs representatives of all the agencies participating in the program. The PNGV may also wish to consider establishing links with the larger transportation community in the course of further efforts to disseminate information about the program status and achievements.

FUNDING REQUIREMENTS

The FY 1996 federal budget has been altered dramatically by changes in federal government priorities, and budgets for the various federal PNGV programs have been reduced below those requested. Final FY 1996 PNGV budgets were unavailable when this report was prepared; therefore the committee was unable to judge the full impact of the reductions.

Meeting the challenge of achieving three times today's fuel efficiency in a prototype vehicle ready for production in 2004, along with all of the other requirements surrounding Goal 3, is extremely difficult. Without question the recent federal budget reductions will delay the program and increase the risk associated with meeting the technical objectives. Reallocating resources to the most promising candidate subsystems within the PNGV program will be crucial in this austere fiscal environment.

Recommendation

With regard to funding requirements, the committee recommends the following:

Recommendation. To be successful, a complex development program such as PNGV must have well-defined plans and objectives, adequate resources, and be supported by sufficient funding. It is incumbent upon both USCAR and the government to ensure that adequate resources for the PNGV program are provided in a timely manner and used efficiently in overcoming the critical barriers to achieving PNGV goals.

TIMELY CORRECTION OF PROGRAM DEFICIENCIES

To maintain continued viability of the PNGV program, the committee strongly urges the government and industry partners to address program deficiencies as soon as possible.

Members of the PNGV are encouraged to meet with the committee at the earliest opportunity to discuss the findings and recommendations of this report and to develop appropriate remedial action.

PEER REVIEWS OF THE PNGV

If the PNGV program is to be properly focused and vigorously implemented and supported as a national goal, there must be further detailed reviews of the technical decisions, research results, and organizational structures of the program. The commitee proposes conducting such expanded reviews in early 1996. As part of that process, the committee will assess the actions taken by the PNGV to address the recommendations in this report.

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2

Introduction

This is the second report of the National Research Council's (NRC's) Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles (PNGV). The committee was established in July 1994 to conduct independent annual reviews of the PNGV's research program and to advise the government and industry participants on the program's progress. The PNGV declaration of intent includes a requirement for an independent peer review "to comment on the technologies selected for research and progress made." To this end, this review was undertaken by the NRC at the written request of the Under Secretary for Technology Administration, U.S. Department of Commerce (DOC), acting on behalf of the PNGV.

The PNGV program is a cooperative research and development (R&D) program between the federal government and the United States Council for Automotive Research (USCAR), whose members are Chrysler Corporation, Ford Motor Company, and General Motors Corporation. The PNGV was initiated on September 29, 1993, by President Clinton with the purpose of enhancing the U.S. domestic automobile industry's productivity and competitiveness while improving the fuel efficiency of today's vehicles. The aims of the PNGV program are to improve automobiles over the next decade and to develop technologies for a new generation of vehicles that could achieve fuel economies up to three times those of today's comparable vehicles. At the same time, these vehicles should maintain performance, size, utility, and cost of ownership and operation and should meet or exceed federal safety and emissions requirements (The White House, 1993).

The PNGV goals and the considerations underlying them are articulated in the partnership's program plan, as follows (PNGV, 1995):

> **GOAL 1—Significantly improve national competitiveness in manufacturing.** Improve the productivity of the U.S. manufacturing base by significantly upgrading U.S. manufacturing technology, including the adoption of agile and flexible manufacturing and reduction of costs and lead times, while reducing the environmental impact and/or improving quality.

GOAL 2—Implement commercially viable innovations from ongoing research on conventional vehicles.
Pursue technology advances that can lead to improvements in the fuel efficiency and reductions in the emissions of standard vehicle designs, while pursuing advances to maintain safety performance. Research will focus on technologies that reduce the demand for energy from the engine and drivetrain. Throughout the research program, the industry has pledged to apply those commercially viable technologies resulting from this research that would be expected to significantly increase vehicle fuel efficiency and improve emissions.

GOAL 3—Develop vehicles to achieve up to three times the fuel efficiency of comparable 1994 family sedans.
Increase vehicle fuel efficiency to up to three times that of the average 1994 Concorde/Taurus/Lumina automobiles with equivalent cost of ownership adjusted for economics.

According to the schedule for Goal 3 that is described in the program plan, by 1997 the PNGV expects to assess system configurations for alternative vehicles and to narrow its technology choices, with the intent of defining, developing, and constructing concept vehicles by 2000 and with the production of prototypes by 2004. The technology areas being addressed include advanced lightweight materials and structures; energy efficient conversion systems (including advanced internal combustion engines, gas turbines, and fuel cells); hybrid electric propulsion systems; energy-storage devices (including high-power batteries, flywheels, and ultracapacitors); more-efficient electrical systems; and energy recovery systems, such as those for efficiently recovering and utilizing exhaust energy and braking energy.

For Phase 2 of the PNGV peer review, additional members were added to the committee to provide the expertise necessary to assess developments in the program since the first review; notably, in the areas of energy conversion, powertrain technologies, and systems analysis. Biographical information on committee members is presented in appendix A. The committee was charged with performing the following tasks:

- Assess the progress of the PNGV program since August 1994 and its response to the recommendations from the first NRC review.
- Examine ongoing research activities in the PNGV, that is, in the various agencies of government (including the pertinent national laboratories and contractors) and at USCAR.
- Assess the relevance of that ongoing research and its management to the PNGV's goals and schedule.
- Prepare a second peer review report.

Consistent with this charge, this second report offers the committee's findings and recommendations based on presentations from the PNGV that were made August 27-31, 1995, in Dearborn, Michigan, and October 30-November 1, 1995, in Washington, D.C. The two committee meetings were supplemented by site visits to Chrysler, Ford, and General Motors R&D facilities by small subgroups of the committee and by the attendance at selected conferences and symposia of individual committee members. (The list of presentations to the committee and other data-gathering activities is provided in appendix B.) Some of the material was presented to the committee as USCAR proprietary information under an agreement signed by the National Academy of Sciences; USCAR; and the U.S. government, represented by the DOC.

The committee started its work with the explicit understanding that the vision, goals, and target dates for the PNGV had been articulated by the President and that the appropriate R&D programs had been launched. On the premise that the PNGV would be seriously pursued by its partners, the committee saw its charge as one of providing independent advice to help the PNGV achieve the goals envisioned. Thus, in its review the committee sought to identify strengths and actions that could enhance the program's chance for success.

The committee has studiously avoided making judgments at this time on the value of the program to the nation; hence, the committee accepted the fuel economy target for Goal 3 as a given. This target is to design and construct a production prototype vehicle (or vehicles) by 2004 that will have, among other attributes, a fuel economy of up to 80 miles per equivalent gallon of gasoline (as measured by the Federal Test Procedure). The committee discussed, but did not choose to question, this fuel economy target, deferring that issue for later discussion following selection of vehicle configurations in 1997. Likewise, the committee accepted the statements for Goals 1 and 2, while noting that they are open ended and do not have quantitative targets and milestones as does Goal 3.

In the foregoing context, the objective of the committee's review was to conduct a review of the R&D program as presently configured and to assess the PNGV program's potential for achieving its goals. Thus, the presentations sought by the committee at its second round of meetings centered around understanding the PNGV's perspectives on the technologies under consideration; key research challenges and priorities; alignment of the program architecture with the goals, schedule, and milestones; metrics for measuring progress; resources deployed in fiscal year (FY) 1995 and planned for subsequent years; and program management within the PNGV.

Key questions for which the committee sought information and insight include the following:

- Are the broad priorities established for the PNGV program reasonable?
- Are there obvious potential technologies not being considered as candidates for the PNGV concept vehicles?
- Does the PNGV program have detailed plans sufficient to adequately describe the work effort and permit effective program management of dedicated resources?
- Does the PNGV program have an effective program management structure for the government and industry organizations involved?

- Does the PNGV program have adequate and dedicated levels of funding and resources required to accomplish the goals and schedules specified in the program plan?
- Is the PNGV program considering all pertinent sources of technology?

This report attempts to answer these overarching questions.

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3

PNGV Response to the Phase 1 Report

In its report issued in October 1994, after the first review of the PNGV research program, the committee offered a number of recommendations for the PNGV's consideration (NRC, 1994). Most importantly, the committee considered the broad priorities and underlying concepts of the program to be reasonable and credible but noted that for the goals of the program to be met or closely approached, well-managed and adequate resources must be devoted to it in a timely manner and it must be pursued with urgency as a national goal.

In this regard, the committee made four major recommendations concerning the need for (1) a strong central government program manager; (2) central control over a unified government budget for critical and core items; (3) a central (integrated) USCAR platform development team with a single technical director; and (4) a sustained national commitment. The committee also offered four additional recommendations directed at (1) developing a technology strategy for the PNGV's research activities; (2) involving suppliers and university researchers in the program; (3) using foreign technology and resources where and when appropriate; and (4) evaluating the implications of future infrastructure and capital needs that would be generated by a successful program.

The PNGV provided a written response to the committee's recommendations in the form of a letter from its Operational Steering Group, dated March 3, 1995. This letter in its entirety is included in appendix C, together with the committee's initial analysis of the response, which was provided to the PNGV prior to the August 1995 committee meeting in Dearborn, Michigan. The committee discussed the response letter with the PNGV at this meeting and assessed PNGV's actions to implement the committee's recommendations. The highlights of that assessment are outlined below.

- Progress, changes in the program, and material presented to the committee during the current review indicate that PNGV has resolved some of the issues raised in the Phase 1 report. PNGV has yet to address other important issues in a substantive way, as discussed in later chapters of this report. The committee's recommendations regarding the major outstanding issues are presented in the appropriate chapters (Infrastructure, Systems Analysis, Program Organization and Management, National Commitment).

- The recommendations dealing with the need for stronger program management and establishment of a USCAR integrated platform development team were overtaken by the industry decision to create proprietary concept vehicles. This decision makes management by "a single platform team" less appropriate; but, in the judgement of the committee, the need for better "defined and staffed management structures" than existed at the time of the first review remains an important issue. Certainly a case can be made that perfectly adequate organizations exist within each of the car companies to perform their in-house tasks, since concept and production prototype vehicle construction is a routine process for them. However, the committee strongly believes that the current coordination mechanism within PNGV does not permit the members of USCAR to fully exploit the leveraged advantages of an integrated organization in pursuit of the program goals. It is the considered opinion of the committee that the appointment of a PNGV-USCAR technical director is even more essential and urgent than at the time of the first peer review, given the diverse approaches of the USCAR members to designing and building Goal 3 vehicles. Further, the committee observed that the government lacks an effective program management organization, with the current program management office operating essentially as an information office. The committee is concerned that the current program management organization on the government side is not conducive to maximizing the contribution of the non-proprietary R&D conducted primarily at government laboratories.

- The previously noted lack of an integrated PNGV program plan is partially overcome by creation of the Draft PNGV Technical Roadmap (dated August 15, 1995), which was provided to the committee just prior to its first meeting, at the end of August 1995 (PNGV, 1995). This document does a good job of describing the major technologies being pursued, the target performance levels and the planned schedule. However, it is deficient in identifying resource requirements and, in some cases, in establishing the critical milestones and quantitative performance measures that must be met to achieve the PNGV goals on time. The committee assumes that the missing details will be added by PNGV in future revisions of the Technical Roadmap.

- The committee's recommendations to combine "major and critical elements of the PNGV program" in a single line item budget has not proven feasible. The current PNGV program on the federal side is composed of a loose assembly of individual projects, a number of which predate the PNGV. These projects aim to satisfy the requirements of both the PNGV and other programs; therefore, the PNGV government program manager has very limited influence over project priorities and resources. In the view of the committee, the mechanisms for program coordination and decision making that will be used for "selecting and integrating technologies and for assessing total costs and benefits" still require definition. The existence and effectiveness of mechanisms were not clear from the material presented by the PNGV to the committee.

- The committee's recommendations "to make an analysis to divide all technologies related to Goal 3 into two categories: current PNGV and post PNGV technologies" and the need to address infrastructure issues as "an integral part of the PNGV program systems analysis" appear to have been favorably received by the program managers. They still remain, however, as significant concerns of the committee. It is the committee's considered opinion that the program would benefit significantly if the major technologies being pursued by the PNGV were critically examined in light of the two categories above and if the infrastructure issues were more directly addressed as an integrated part of the PNGV's technology tradeoff studies and decision process for technology selection in 1997.

- Many of the remaining recommendations from the Phase 1 report have been addressed or explained by the PNGV so that, while not completely resolved, they no longer present major concerns to the committee. These issues include the degree of public outreach and the extent of supplier and university involvement in the program. While a start has been made to benchmark foreign technology developments, the committee considers it important for the PNGV to analyze available data fully, make more comprehensive assessments, and take action to modify the PNGV program as appropriate.

- In the committee's view, the DOD, the DOT, and the NASA still need to be more supportive and integrated into the PNGV research program. The relevance of certain ongoing R&D programs funded by these agencies to the PNGV technical objectives militates in favor of this view.

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4

Goals 1 and 2

Given the lack of quantitative objectives for Goals 1 and 2 and the time constraints on conducting this second peer review of the research program of the PNGV, the committee chose to focus on activities relating to Goal 3. The following discussion aims to provide the reader with a brief overview of PNGV activities and achievements directed towards Goals 1 and 2. The committee noted that the absence of quantitative objectives complicates any assessment of progress.

Achievements in Goal 1 and Goal 2 programs form an important base on which to build in developing Goal 3 technologies; for example, by establishing commercially viable manufacturing methods and obtaining data on the crashworthiness of composite vehicle structures. These programs will supplement Goal 3 technology development efforts and will provide useful supporting information for subsequent market-based assessments of advanced vehicle technologies.

GOAL 1

Objectives for Goal 1 (significantly improve national competitiveness in manufacturing) are being formulated by the PNGV in response to needs identified in the context of Goal 2 and Goal 3 technology development programs, notably for low-cost, high-volume manufacturing processes. The manufacturing program includes efforts to:

- improve design and development processes to shorten lead times and achieve cost reductions
- develop new manufacturing systems that will increase productivity
- develop and validate new vehicle assembly systems that will assure the ability to integrate new technologies and allow increased productivity

No specific quantitative objectives (e.g., productivity levels, cost, quality) have been defined for specific vehicle systems, subsystems or component developments.

At its Dearborn, Michigan, meeting, the committee was provided with a paper summarizing the progress and status of Goal 1 activities. A consolidated USCAR listing of 256 candidate technologies was compiled and compared with an inventory of government agency projects to identify synergies and to avoid possible redundances. The list was consolidated to 196 technologies with the potential to impact PNGV goals. These 196 technologies were further prioritized into 96 high-priority, near-term, generic manufacturing needs; 47 Goal 3 vehicle enablers; and 53 medium- and low-priority technologies. Technologies in the first category were further reduced to 35 (following reviews with the individual Chrysler, Ford, and General Motors manufacturing organizations) from which the 16 highest priority projects were selected covering the following categories:

- simulation and modeling
- systems/software integration
- agile, flexible manufacturing
- alternative processes
- test methodology
- current process optimization

Funding requirements for the 16 high-priority projects are being identified.

Manufacturing representatives from USCAR have now been assigned to each of the product technology teams (see PNGV Technical Organizational Structure, figure 9-1), and specific manufacturing needs in each area are being assessed. Notable achievements demonstrated by USCAR programs with suppliers include high-volume structural resin-injection-molding composite processes capable of producing an underbody crossmember; a slab and belt cast-aluminum sheet fabricated in automotive alloys with a potential cost of $1/lb; and resolution of forming, joining, and painting issues in a new, high-volume application of aluminum closure panels.

The committee noted that reduced funding levels are threatening the scope of the 16 proposed Goal 1 high-priority activities. Projects with specific direct benefit to vehicle weight and cost reduction, such as aluminum die-casting, high-throughput hole-making, and springback predictability, have not received funding from the National Institute for Science and Technology under the Advanced Technology Program. The uncertainty of government funds is forcing the manufacturing teams to narrow the scope of the 16 selected programs.

Demonstrating the reliability of new manufacturing technologies in a commercial environment requires time. The choice of promising Goal 3 technologies for selection in 1997 may well be limited by the absence of Goal 1 proven manufacturing processes that offer significant time and cost advantages. Increased flexibility in assigning funds to the most critical programs would minimize this concern.

GOAL 2

Projects in support of Goal 2 (implement commercially viable innovations from ongoing research on conventional vehicles) span the time horizon from near-term applications in current production vehicles to research and development that might enhance the feasibility of Goal 3 technology selections, besides being applied to conventional vehicles. A variety of projects—many involving several of the national laboratories—are being carried out under the auspices of the USCAR consortia (see appendix D). Additional programs are being conducted individually by Chrysler, Ford, and General Motors. Many of the Goal 2 projects grew out of USCAR collaborative activities that were in place prior to the establishment of PNGV. Several workshops have been held to develop a priority list of fuel-economy-related research objectives and over 60 different development areas have been identified and prioritized.

A number of Goal 2 powertrain projects are being conducted within the USCAR Low Emission Partnership (LEP). The LEP encompasses a wide variety of developments spanning the field from evaporative emissions, fuel preparation and metering, through combustion, and on to after-treatment and in-use compliance. Five national laboratories are actively involved, each with appropriate, well-defined projects aimed at hastening near-term application of their technologies and support of the emission reduction needs of some of the Goal 3 vehicles. Additional projects are under development with NASA. Cooperative Research and Development Agreements (CRADAs), which target powertrain development needs, also exist between individual companies and some national laboratories. Some of this activity is not categorized as precompetitive.

Major areas of progress in Goal 2 include the following:

- successful crash testing of a Ford Escort vehicle with a front end made of composite material, which provided information about the behavior of composite vehicle structures under crash conditions
- completion of the design of a truck pick-up box using composite material, with projected 28 percent weight saving compared with a steel structure
- production of prototype test sections of dual-wall, stainless-steel manifolds using a new superplastic forming process for stainless steel. The PNGV is investigating energy-conserving, double-wall exhaust manifolds to reduce cold-start emissions.
- development of novel hydrous metal oxides for sulfur-resistant NO_x reduction catalysts and a new cleaning process for zeolite catalysts

There is some concern among the PNGV industry partners that future decisions regarding funding for CRADAs supporting Goal 2 may not be consistent with PNGV priorities. U.S. Department of Energy (DOE) program managers and industry technical representatives planned to participate in an exploratory meeting in early January 1996 to discuss technical priorities and examine opportunities for reallocating resources in support of PNGV technical objectives.

As noted elsewhere in this report, because of the lack of quantitative objectives for Goals 1 and 2 and the time constraints, the committee has not performed a detailed examination of the objectives and status of these Goal 2 projects. The committee's focus has largely been on the PNGV programs for Goal 3.

ISSUES

The committee noted that Goal 1 and 2 programs carry substantially less technical risk than Goal 3 programs. In addition, considerably less PNGV effort is being applied to the former activities. Nonetheless, progress is being made towards meeting Goal 1 and Goal 2 objectives, with technological advances and achievements being introduced into production as they occur. The committee's main concern regarding Goal 1 and 2 programs continues to be the absence of quantitative objectives. This deficiency complicates any attempt to assess progress.

5

Structural Materials

The challenge for materials technology is to support a dramatic reduction in vehicle weight to achieve the PNGV goal of up to three times today's fuel economy. Lighter weight PNGV vehicles should maintain the performance, size, utility, and cost of ownership of today's comparable vehicles, and their operation should meet or exceed federal safety and emissions requirements. The sensitivity of vehicle weight to the efficiency needs of the powertrain is depicted in figure 5-1. An ability to achieve in excess of 40 percent vehicle mass reduction could reduce the demands for power source thermal efficiency from over 50 percent to approximately 40 percent. At a vehicle mass reduction of 40 percent, advanced conventional power sources have the potential to attain the necessary thermal efficiency to reach the objective of three times today's fuel economy. Thermal efficiencies of approximately 40 percent are associated with more mature power sources, which are the most likely to meet the necessary performance requirements within the PNGV timeframe. At the other end of the scale, power sources with much higher efficiencies, such as fuel cells,[1] may be less demanding in terms of needed vehicle-mass-reduction requirements but are relatively immature in their development and, hence, have a lower probability of meeting PNGV schedules.

THE PNGV APPROACH

The objectives for vehicle mass reduction in support of the PNGV Goal 3 vehicle have now been established, as shown in table 5-1. In pursuit of these objectives, the PNGV vehicle engineering team is directing manufacturing, materials, and system analysis teams in support of subsystem development.[2] Directives are established through workshops where the PNGV technical teams and vehicle engineers identify potential materials and applications. Challenge tables have been created to prioritize developments needed to support technology selection in 1997. These tables compare present state-of-the-art technologies with PNGV requirements. A series of workshops has been held with materials suppliers to identify materials research projects in response to the developments identified in the challenge tables. Workshop participants are encouraged to submit white papers outlining their proposed research. Opportunities may exist to leverage materials developments in non-automotive areas—notably in the aerospace sector—in pursuit of PNGV goals. Advanced alloys, ceramics, and composite materials developed for a range of high-performance applications may offer potential for automotive use.

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[1] Assumes use of hydrogen fuel stored onboard the vehicle.

[2] The PNGV technical organization structure is addressed in chapter 9.

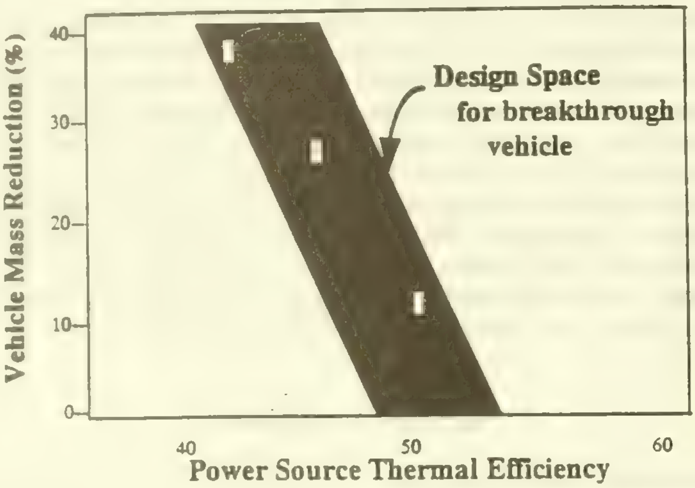

FIGURE 5-1 PNGV design space. SOURCE: PNGV, 1995.

MATERIALS OPTIONS

Three candidate materials have now been identified for body structure; namely, steel, aluminum, and graphite fiber-reinforced, polymer-matrix composites (GFRP). Many opportunities exist to develop improved materials for candidate powertrain components, such as fuel cells, flywheels, and ultracapacitors. However, no major studies in this area have yet been initiated by the PNGV Materials and Structures Team. Therefore, the present discussion is limited to materials for vehicle body structure.

TABLE 5-1 Vehicle Mass Reduction Targets for PNGV Goal 3 Vehicle

System	Current Vehicle (lb)	PNGV Vehicle Target (lb)	% Mass Reduction
Body	1,134	566	50
Chassis	1,101	550	50
Powertrain	868	781	10
Fuel/Other	137	63	55
Curb Weight	3,240	1,960	40

SOURCE: PNGV, 1995.

Steel

Steel is the dominant material in use today for automotive body structures. Efforts sponsored by the American Iron and Steel Institute (AISI) are underway to reduce the weight of steel-intensive vehicles by 20 percent or more through improved design techniques, advances in manufacturing technology, and wider use of high-strength steels. An analytical study by the Ultralight Steel Auto Body international consortium forecasts a weight of 205 kg (450 lb) for a body-in-white,[3] based on incorporation in the design of off-the-shelf, near-term approaches that relate primarily to Goals 1 and 2 (Martin, 1995). Although increased use of high-strength steel was included in the study, weight reductions were achieved primarily through design approaches rather than new materials. Such considerations are applicable to other metallic materials. Current activities form a basis for exploring and using more advanced technologies directed toward Goal 3 needs.

Ongoing studies are investigating steel-based materials with improved strength, ductility, and stiffness-to-weight ratio; methods for strengthening after forming are also being considered. Manufacturing studies are addressing increases in production rates for new processes for stamping and assembly, including challenges in joining dissimilar materials, such as the welding of steel to aluminum. A major focus is the development of a systems-based design approach that can be implemented on a desktop computer-aided design system rather than requiring a mainframe supercomputer, with associated accessibility problems. An important issue, yet to be addressed by the PNGV, relates to the design process and how systems analysis will be used to evaluate tradeoffs between various objectives for materials and components. The specification of low-cost conventional materials in some areas can be balanced with high-cost advanced materials in other areas to achieve targeted vehicle weight reductions optimized with respect to cost (both piece and life cycle).

Available data and information on planned programs indicate that 20 percent overall vehicle mass reduction would be a very challenging objective for steel (Sherman, 1995). However, the advantages of this material are that it is the lowest cost material (per pound) of the three candidates; it has the largest technical experience base for automotive structures; and it would not need either the added investments in new manufacturing processes required for aluminum or the major investments necessary to support GFRP.

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[3] Defined as the vehicle assembly, comprising the assembled but unpainted body, excluding glass, trim, and chassis items.

Aluminum

The intensive use of aluminum is forecast to yield weights close to target values for the overall vehicle. However, based on current manufacturing practices, it is unlikely the target weight can be achieved within the PNGV timeframe with no cost increase. While the forecast weight savings for aluminum usage are not controversial, the outstanding tasks listed by the PNGV suggest that more data are needed on the strength of aluminum weld bonds and crashworthiness of the aluminum intensive vehicles (Sherman, 1995). Weight reductions of up to 45 to 50 percent for body/chassis are considered attainable, based in part on supporting data from Ford's Aluminum Intensive Vehicle (AIV) design and testing program, which included crash vehicles (Sherman, 1995).

Analysis by the PNGV Materials and Structures Team suggests that, taking into account potential weight savings, a cost of $1/lb for aluminum sheet would be competitive with steel for vehicle structural applications. Data from recent experimental manufacturing studies for sheet aluminum should be helpful in assessing the feasibility of meeting the $1/lb cost target. Recent workshops with aluminum suppliers will likely yield many white papers on technical issues, together with suggestions for materials solutions that can be investigated in the coming year (Sherman, 1995). Broader questions to be addressed (through systems analysis) relate to the life-cycle cost of aluminum, that is, the overall cost from mining of bauxite ore through use, recycle, and reuse; and to the availability of bauxite ore, smelters, and material formers to meet the requirements of a potential annual market in the United States for 15 million aluminum-intensive vehicles.

Composites

The PNGV has developed a challenging vision statement for composite materials as follows: "To develop and demonstrate reinforced polymer composite manufacturing processes capable of producing complex, high-volume vehicle structures at low cost, which meet all manufacturing and vehicle performance requirements."[4]

There are major design and manufacturing process changes involved in transitioning from a steel-based to a composite-based vehicle. The design of the body structure has to be approached quite differently to take advantage of the unique properties of GFRP and the relationship of specific manufacturing details, to final in-service performance of one component, as well as the ability to integrate two or more existing components into one. For composites, manufacturing details, such as the method of fiber preform fabrication, fiber architecture, fiber angle, braid material properties, and molding processes, as well as the choice of fiber and resin systems, can be manipulated to alter substantially the in-service performance of a component. Thus, unlike most automotive structural metallic materials, for which the manufacturing processes generally provide simply a means for attaining a specific geometrical shape, the manufacturing process for composites is an essential determinant of both the properties and geometry of a finished part. Thus, an integrated product design approach to composite applications in automotive structures is required to evaluate adequately the cost effectiveness of composites in meeting the cost and performance requirements for Goal 3. Investigations of such product design approaches are underway in the USCAR Automotive Materials Partnership (appendix D).

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[4] High volume is defined to be greater than 250,000 units. The low-cost requirement refers to the cost in an assembled vehicle.

Intensive use of GFRP could readily meet the 50 percent body and chassis weight-reduction target for a Goal 3 vehicle, but today's price of $8 to $15/lb for graphite fibers would result in a major cost penalty of approximately $6,000 per vehicle. Current projections suggest that an annual demand for one billion pounds of graphite fiber could drive its cost down to between $3/lb and $5/lb, within reach of the PNGV cost targets (Michno, 1995). Testing of glass-fiber-reinforced composites using a Ford Aerostar vehicle underbody crossmember has shown high-volume potential for lower cost, recyclable, structural resin-injection-molded composites.

Limited progress has been reported by PNGV to date in establishing the crashworthiness of composite structures in front, side, and rear collisions. Crash energy management needs to be resolved with extremely high confidence. Computer simulation of crash events for composite materials cannot currently be made with confidence. Consequently a large number of prototypes must be built and crashed under a variety of conditions that can occur in the field to develop the databases, computer models, and analytical methods needed to provide a reliable predictive capability. However, such tests cannot be performed until the matrix resin for the composite has been selected. The choice of resin also greatly influences recycling methods, as well as joining and repairability techniques.

ISSUES

The PNGV has planned its next steps towards achieving the desired materials objectives as follows:

- Based on white papers developed following the supplier workshops, help initiate research projects with materials suppliers and other organizations aimed at meeting the challenges for aluminum and composite vehicles.
- Work with the AISI to develop structural concepts for steel vehicles and define materials challenges and research needs.
- Pursue activities defined in the Technical Roadmap for chassis and powertrain materials. The powertrain technical teams, materials suppliers, universities, and government laboratories will be involved in these activities.

The committee concluded that progress towards the PNGV materials objectives has clearly been made through the process (challenge tables, supplier workshops, white papers, etc.) established by the Materials and Structures Team, and through the work of the USCAR Automotive Materials Partnership. Materials suppliers are major supporters of the program and are investing heavily in technology development for both metals and composites, including innovative processing techniques. In particular, the PNGV materials program has made significant progress in developing steel and aluminum for structural automotive applications.

Despite some progress, the composites program is lagging, with no clearly scheduled activities that would enable this class of materials to be viable alternatives to steel and aluminum by 1997. To assess adequately the potential of composites to meet program objectives, vis-à-vis high-strength steel or aluminum, the PNGV team needs to place high priority on an integrated composites evaluation program involving feature-based computerized design, analysis of manufacturing costs and tradeoffs, modeling of composite automotive structure performance under impact, and the evaluation of newly developed manufacturing technology oriented towards low-cost, high-volume production.

RECOMMENDATIONS

> **Recommendation**. The systems analysis effort recently initiated by the PNGV should be used to drive the optimization of materials usage for the various vehicle components based on part configuration tradeoffs and on incorporation of data on manufacturing costs, structural effectiveness, recyclability, and other properties.
>
> **Recommendation**. The USCAR should continue to use the process it has developed—incorporating its substantial leverage through integrated industry programs—to pursue the very promising developments in steel and aluminum materials made by materials suppliers and trade associations. The development of innovative manufacturing processes for aluminum and steel should be encouraged and accelerated.
>
> **Recommendation**. The PNGV should establish an integrated product design program to provide better evidence for the advantages and viability of using polymer-based composites for automotive body structures. The program should:
>
> - Develop computerized feature-based design and decision support tools to enable an integrated product design evaluation of the cost effectiveness of composites for vehicle structural applications.
> - Validate the projected cost of $3 to $5/lb at high-volume through production process pilots.
> - Address the development of a database and models to establish the crashworthiness of composite structures.
> - Take into account relevant experience with composites in the aerospace industry.

The approach adopted to date by the PNGV (materials workshops, white papers, etc.) should be pursued on an accelerated schedule as a basis for establishing the above program.

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6

Powertrain Developments

POWERTRAIN TECHNOLOGIES BEING STUDIED

Research that provides substantial improvement in the efficiency of powertrains compared with that of current commercial systems is crucial to the success of the PNGV. The importance and difficulty of achieving this improvement is underscored by the fact that, after almost 100 years of internal combustion engine refinement and improvement, typically, only 12 to 20 percent of the energy in the fuel used reaches the wheels to propel today's passenger cars. To meet PNGV goals, roughly a twofold improvement in powertrain efficiency must be achieved while retaining the size, reliability, durability, safety, and affordability of today's cars; meeting even more stringent emissions and recyclability levels; and employing components capable of being mass produced and maintained in a manner similar to current powertrains.

Even when combined with reductions in vehicle mass, aerodynamic drag, tire rolling resistance, and other energy-saving vehicle design parameters, the PNGV technical team estimates that achieving the Goal 3 fuel economy target (up to three times fuel efficiency of today's comparable vehicle) will require a powerplant with at least 40 percent thermal efficiency (PNGV, 1995). Achieving this efficiency by incremental improvements to current gasoline engines is unlikely. Therefore, a variety of alternative energy conversion devices and drivetrain components are being considered by the PNGV. None of these alternatives is, at present, suitable for passenger car application without further development. Moreover, many combinations are possible; therefore, system tradeoff analyses must be performed to fully understand the fuel efficiency potential of each. For instance, adding hybrid and regenerative braking driveline[1] components reduces the powerplant efficiency gain needed for the PNGV Goal 3 vehicle but increases the size, weight, complexity, and cost of the complete powertrain. This kind of first-order qualitative analysis has resulted in the powertrain technologies listed below. These technologies are currently being pursued by PNGV for Goal 3 vehicles, all of which will operate as hybrid systems.

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[1] The term driveline (or drivetrain) typically refers to the transmission system from engine output shaft to driven road wheels.

The powertrain technologies being pursued by the PNGV for Goal 3 vehicles are as follows:

- four-stroke DICI engines
- gas turbines
- stirling engines
- fuel cells
- reversible energy-storage devices (namely, batteries, flywheels and ultracapacitors)
- electrical and electronic power-conversion devices

Hybrid powertrain systems are attractive to increase powertrain efficiency for two reasons. When combined with a suitable energy-storage device, these systems allow the possibility of recovering a significant portion of the kinetic energy of the vehicle as it decelerates. They also allow the primary energy converter (engine or fuel cell) to be smaller and to operate under load and speed conditions that are independent of the vehicle's immediate needs. This reduces its size and permits its efficiency to be optimized. In addition, this arrangement allows an engine to operate at a speed and load that are independent of the vehicle, and increases the feasibility of using powerplants that would otherwise be unsuitable for passenger vehicles. Emissions can also be reduced significantly, especially at startup when the car can start without the engine.

Both series and parallel hybrid configurations are being considered. In the series configuration, all of the engine power is transmitted to the wheels through electric machines. In a parallel configuration, the engine supplies some power directly to the drive wheels through a mechanical transmission, and this is supplemented by electrical machines and an electrical power source. Continuously variable transmissions (CVTs) allow the relationship between engine speed and vehicle speed to be changed at will and are candidates for the parallel hybrid application. It appears that little or no work with respect to CVTs is being conducted on behalf of the PNGV program in the United States. However, foreign firms are continuing to develop such transmissions (Dancey, 1995; Liebrand, 1995). The committee, therefore, believes that these developments should continue to be incorporated into the PNGV agenda.

Under Goal 2, the PNGV is pursuing a number of powertrain-related developments with varying levels of effort. Some of these are also applicable to Goal 3 requirements, notably:

- various emission reduction mechanisms
- high dynamic range engines
- high expansion ratio engines
- direct injection diesels
- spark ignition engines

- fuel changes to improve efficiency and reduce emissions
- wide ratio and continuously variable transmissions
- reduced engine and driveline losses

The PNGV has concluded that gasoline spark-ignited, internal-combustion engines and straight electric vehicles (as opposed to hybrid electric vehicles) do not have the potential to satisfy Goal 3 requirements within the PNGV time frame (see appendix E). The committee concurs with this conclusion, based on its understanding of the status of the associated technologies. However, improvements in the spark-ignited reciprocating engine continue to be pursued under Goal 2. Likewise, the USCAR partners are pursuing electric vehicles as independent developments.

The committee concurs that the technologies listed above are relevant and appropriate choices. It is not obvious to the committee that any high potential candidates have been overlooked. At this time, however, there is no methodology or comprehensive study that justifies PNGV's technology slate on the basis of potential gains and probability of success in meeting Goal 3 objectives. Such a study would assure that other equally meritorious technologies have not been overlooked and would provide a framework for evaluating future developments. For this reason, the committee considers such a study to be worth undertaking and believes that the underlying methodology would be very useful in the selection process planned to focus research efforts past the year 1997.

The PNGV Technical Roadmap represents an important accomplishment during the past year (PNGV, 1995). This document includes a master schedule for the selection and development of technology, together with parameter targets that each major component must meet by the end of 1997, 2000, and 2004. This compilation provides the technical teams with first order requirements for performance and schedules. More refined systems analyses and packaging studies are still needed to provide detailed specifications for each component and to enable interface and tradeoff studies between them. Although these analyses and studies are just starting on a cooperative basis in PNGV, the individual car companies (Chrysler, Ford, and General Motors) have each conducted proprietary studies of their own.

The absence at USCAR of any comprehensive systems analyses and quantified assessments of development risks for the technologies under consideration by PNGV means that resource allocation for the technology program must be based mainly on the past experience of the industry partners. However, the PNGV program involves technologies without automotive precedent and requires breakthroughs in both new and existing automotive technologies. Therefore, the committee believes the acquisition of effective systems analysis capability and tools at USCAR should be a very high priority for the PNGV. For example, systems analysis models must be sufficiently sophisticated to address safety issues for hybrid vehicles, which will need to meet all the safety requirements for conventional automobiles.

KEY TECHNOLOGY SUMMARIES

Four-Stroke Direct Injection Compression Ignition Engines

Development objectives for the thermal efficiency, specific weight and specific power, cost, durability, NO_x, and particulate emissions of the Direct Injection Compression Ignition (DICI) engine have been clearly specified and compared to today's engines that use diesel fuel in the PNGV Technology Roadmap. This set of objectives provides a basis against which to evaluate the adequacy of the program effort to achieve the needed improvements. A thermal efficiency improvement of 8.4 percent (from 41.5 to 45 percent) is sought, but a gain of 40 percent in specific power is targeted to minimize the higher weight associated with structures to contain the high, peak cylinder pressures typical of these engines. The targeted emissions reductions of 50 percent in particulates and 67 percent in NO_x appear to be the most challenging of the objectives. A thermal efficiency of 45 percent will still require a very large mass reduction in the vehicle to achieve a threefold increase in fuel economy. This may force the use of expensive composite structural materials, which puts pressure on the cost target.

PNGV progress to date has been limited to benchmarking, target setting, and analytical studies with engine subsystem development scheduled to begin at the end of 1995. Some diesel engine research programs were underway prior to 1994 between the federal laboratories and USCAR, and program proposals were made to the DOD, Tank Automotive Command (TACOM) for funding in alternate fuels, engine structure, and materials tradeoffs. These activities are now coordinated by the PNGV. In addition to these efforts, some of the domestic original equipment manufacturers (OEMs) have substantial in-house, largely overseas, DICI engine development programs. The objectives of these in-house programs are being realigned to address the specific needs of a smaller displacement, light-duty engine for the PNGV hybrid vehicle application. The most promising advancement noted by the committee in these programs has been the demonstration of a lean NO_x catalyst with improved steady-state peak efficiency. This result has come from the cooperation of five national laboratories and three OEMs through the USCAR Low Emission Partnership. An effective, durable, low-cost, lean NO_x catalyst would substantially improve the commercial practicality of both the DICI and the lean-burn, spark-ignited engine.

Progress in the diesel research programs now being considered by the PNGV appears to the committee to be commensurate with the limited funding available to date. However, requests by the DOE to fund hybrid vehicle systems and light-duty engine development have been reduced for FY 1996. A detailed milestone list and schedule have been developed, and the program is about to begin an intensive and expensive engine subsystem hardware evaluation. The cost of building and testing advanced fuel systems, cylinder heads for combustion development and engine-out emission reduction, in addition to the development of unique exhaust treatment systems, will far exceed the funds available. Significant results from such testing must be obtained to support an appropriate technology-selection decision in 1997 by the PNGV prior to continued development for the concept and production prototype vehicles.

Commercialization of an advanced DICI engine will be highly dependent upon the ultimate exhaust emission standards that are promulgated. If the standards are set to be more stringent than the current ultra low emission vehicle (ULEV), DICI engines could essentially be ruled out of the marketplace. Possible tightening of particulate emissions standards in the future, given (1) new knowledge on the health impacts resulting from particulate pollution and (2) public concerns about pollution from heavy-duty diesel trucks and buses, would also affect the commercialization of advanced DICI engines. The DICI engine development will also have to overcome the label of a "conventional engine" development program. In the committee's view, a variable geometry turbocharged, direct-injected, variable-swirl, compression-ignition engine with a unique lightweight structure, complex high-pressure fuel system, using sophisticated electronic controls and exhaust after treatment should not in any way be considered "conventional." It currently is the most promising alternative to achieve the goals of the PNGV program within the prescribed time frame.

Gas Turbine Engines

Gas turbine engines have been identified as one of the most promising technologies for the hybrid vehicle. The primary reasons for this are the very high power-to-weight ratio of gas turbines, the relatively low uncontrolled exhaust emissions, and the fact that gas turbines can use virtually any type of fuel.

In general, R&D within and outside the PNGV has demonstrated progress in developing gas turbine engines for automotive applications. Partly, this is because of the enormous advances in automotive electronics and precision control capability that can now be applied to the gas turbine system. Among the most notable achievements are the turbo-alternator designs and fuel and control systems developed by Allied Signal and Allison. There is also the expectation that high-performance bearings that do not require oil are far enough along in development to be considered practical for gas turbine applications. Other areas where significant progress has been made are in the area of combustion—especially reducing emissions through staged burners—and post-combustion controls through use of catalytic converters and the pre-heating of catalytic converters and other components by energy-storage systems; heat recovery systems, especially smaller, lighter weight heat exchangers and better seals; and in the design of high-efficiency, low-cost alternators.

In each of the areas mentioned, PNGV has made some advances in the past year. However, with the possible exception of the fuel control system, the pace of achievements in these areas—and also in reducing costs—is as yet insufficient to predict at this time an unequivocal technology selection decision by 1997.

PNGV's progress to date is behind schedule, in part for budgetary reasons. There have also been major technical roadblocks. Among these are the critical issues of manufacturing reproducibility of high-temperature, structural-ceramic components and the aerodynamic design of small compressors and turbines with sufficiently high efficiency in the relatively low-power hybrid-vehicle applications. Turbine inlet temperatures of around 2,500°F (1,370°C) (i.e., above normal operating temperatures for conventional turbine blades) are essential to achieve the thermal efficiency required to meet Goal 3 performance targets. Achieving these targets requires either ceramic blades, which must also provide the strength, anti-erosion, and other characteristics necessary for durability, or active cooling. Cooling is not promising in such small components and, as far as the committee is aware, is not being considered to any great extent within the PNGV. Although some aircraft gas turbines operate above 2,500°F (1,370°C), it is the committee's understanding that efforts to adapt this technology for automotive powerplants have not been successful to date.

The pursuit of ceramic materials for high-temperature turbomachinery has a long history and has yielded advances in the knowledge base. Indeed, many millions of dollars have been spent over many years in this area in support of automotive and military projects, especially in the United States. Unfortunately, in spite of this sizable effort, no satisfactory materials or fabrication techniques have been found that could extend to the type, size, and cost requirements of engines suitable for the PNGV application. Specifically, the material technology is expensive, even for the raw materials alone. Also, the process of forming them into the proper shapes is costly. There are problems in reducing the ceramic components to the size required, while still meeting the essential performance criteria (e.g., for strength, durability, and precision).

The other important technical issue for the PNGV gas-turbine application is heat recovery. To achieve the efficiency necessary, it is essential to recover a significant portion of the turbine exhaust heat. Using heat exchangers to recover part of this energy for transfer back into the compressor discharge gas is difficult and requires large, heavy, and expensive heat exchangers. Although progress has been made in the past year, further work is needed to reduce the size, weight, and costs of the necessary heat exchangers. Consequently, the heat recovery area is critical and must be satisfactorily resolved if the gas turbine is to be seriously considered as a prime mover within the PNGV schedule.

Gas turbine engines face a major cost hurdle to achieve the PNGV goal. Historically, high-speed, high-temperature turbomachinery has been more costly than less compact, heavier powerplants. The need for precision ceramic components may render the cost target difficult to achieve within the PNGV time schedule.

Stirling Engines

The Stirling engine is being considered as an alternative in the General Motors hybrid electric vehicle program. Stirling engines have some of the same advantages as the gas turbine engine: exhaust emissions are very low, and virtually any fuel can be satisfactorily used. Earlier attempts to use this engine in automotive applications showed it to be uncompetitive in size, weight, and cost. Being a closed cycle engine, all of the heat supplied to and rejected from the engine must go through heat exchangers, and this is a fundamental drawback. However, development of this engine for stationary applications has continued, and progress has been promising enough that its use by the PNGV has not been ruled out. In the absence of further information from the PNGV on the current status of Stirling engine development, the committee chose not to comment on the attractiveness of this technology other than noting the advantages stated above.

Fuel Cells

The challenges faced for fuel cell system development are clearly set out in the PNGV Technical Roadmap, which lists them as: ". . .cost, efficiency. . .unattended reliability and durability." In addition it states, "PNGV cost and efficiency targets are the major challenges for fuel processing, while cost and energy density targets are the major challenges for hydrogen storage." System targets set forth in the Technical Roadmap include a peak power efficiency of 53 percent, compared with an estimate of 45 percent today; and a power density of 0.4 kW/l, and specific power of 0.4 kW/kg, both of which are about twice the estimated state of the art today. It is important to note that the efficiencies quoted above are based on the use of hydrogen as a fuel.[2] Since it is unlikely that hydrogen can be stored on board a vehicle under the constraints established by PNGV Goal 3, vehicle efficiency calculations based on fuel sources may be more appropriate.

The cost reduction target is by far the most challenging—from over $200 per kW today to $30 per kW (in 1995 dollars) by 2004. Hydrogen storage targets of 2 kWh/l and 3 kWh/kg can only be approached with costly and energy-inefficient liquid storage systems. Today, such storage of gaseous hydrogen would require five times the PNGV target size and 2.7 times the target weight, as specified in the Technical Roadmap. The committee did not receive estimates for the current size and weight of fuel processors for converting hydrocarbon or methanol fuel to hydrogen on board the vehicle, but targets of 0.5 kW/l and 1.0 kW/kg have been established by the PNGV.

A wide variety of fuel-cell-related activities have been sponsored under the DOE Fuel Cells for Transportation Program. Participants include the three USCAR partners, several national laboratories, private companies, and universities. There is general agreement that the proton exchange membrane (PEM) fuel cell is the best candidate for automotive applications. The General Motors program, in Phase 2, is concentrated on using a methanol reformer and has supported PEM fuel cell development at Ballard Power Systems, Inc., in Canada. (The PNGV Technical Roadmap lists system targets but not individual stack-power or energy-density targets.) The Chrysler and Ford programs are in Phase 1 and are focused on reducing system cost and addressing hydrogen infrastructure issues, respectively.

Significant progress has been reported on membrane and electrode development, which has resulted in vastly improved power densities and reductions in platinum loading. Ballard reports that stack-power density has increased from 140 W/l in 1992 to 570 W/l in 1995 and projects a value of 720 W/l in 1996. With these improvements, the cost of the electrode materials for a fuel-cell stack are relatively low, but the fabrication costs of graphite bipolar plates are extremely high. Lower cost metallic or plastic bipolar plates and automated electrode fabrication techniques are being pursued, and it is reported that the current membrane costs might be reduced by a factor of 10 with high-volume production.

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[2] Efficiencies of overall systems, including a reformer, are frequently not known and also depend on the reformer fuel. The use of an efficiency based on hydrogen is helpful as a standard and for comparison purposes.

Another major technical barrier is water, thermal, and air management. Current stack engineering efforts are aimed at self-humidifying the cells, and these efforts should be intensified. A great deal of progress will have to be made in order to meet the 1997 PNGV milestones.

Fuel storage and supply represents another critical area. It appears unlikely that liquid hydrogen can be used on board the vehicle, mainly from an energy efficiency point of view but also due to safety and refueling concerns. In addition, supplying this fuel on a wide scale presents daunting problems, as indicated by work conducted by BMW and DaimlerBenz in Germany on technology and infrastructure issues for future hydrogen-powered vehicles (Klaiber, 1995; Tachtler, 1995).

Several small (10 kW) methanol reformers have been designed; projections of the overall efficiency for the process of producing methanol to provide mechanical energy are on the order of 20 to 25 percent, which is approximately half the target value specificed in the PNGV Technical Roadmap.[3] Hydrocarbon partial-oxidation processors may be slightly more efficient overall and are beginning to be explored. This issue of fuel storage and supply faced by the fuel cell system may be the most difficult problem of all. Significant additional resources will be needed to develop an efficient, practical way of generating hydrogen on board personal passenger vehicles.

In summary, fuel cells, in the long term, offer the potential of high-energy conversion efficiency. Cost remains a major problem. Mass production alone is not enough to drive the cost of today's state-of-the-art fuel cell systems down to acceptable levels. No satisfactory fuel supply solution is apparent, although some candidates have certain attractive features. Hydrogen infrastructure and storage concerns force consideration of using on board fuel processors, which, in turn, substantially compromise the efficiency advantage of the fuel cell. As noted above, substantial progress is being made, but several major research breakthroughs are still needed for this technology to meet PNGV technical targets and schedules.

Energy Storage Devices for Hybrid Electric Vehicles

Energy storage remains an essential component of hybrid electric vehicles. Energy storage not only gives the capability for recovering a significant portion of the kinetic energy of a vehicle when being decelerated or stopped, it also adds another dimension to the flexibility of the overall powertrain in the case of the heat engine or fuel-cell hybrid vehicle. In the past a number of storage technologies have been considered and investigated to varying degrees. Among these were elastomers, hydraulic springs, compressed air, flywheels, ultracapacitors, and batteries. Only the latter three have been given major consideration by the PNGV and, while it seems likely that they are indeed the best candidates for energy storage, it would be useful if the criteria for their selection were better articulated.

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[3] Methanol is converted to hydrogen in a fuel processor composed of a reformer and a shift converter; the conversion efficiency is approximately 70 percent. In the reformer, methanol reacts with steam over a catalyst to produce hydrogen, carbon dioxide, and small amounts of carbon monoxide. Since the latter poisons the anodic reaction of hydrogen in the fuel cell, the mixture of gases is passed through a water-gas shift reactor to reduce the amount of carbon monoxide.

Batteries

Batteries represent the most mature technology among the three energy-storage systems being considered by the PNGV. Further, from a systems integration standpoint, batteries probably offer the most advantages. However, there are significant problems with all of the batteries being considered for hybrid electric vehicles at this time, including the lead-acid, nickel-cadmium, nickel-metal hydride, lithium-ion, lithium-polymer, sodium-sulfur and zinc-air batteries. Most battery R&D (with the exception of the lead-acid and nickel-cadmium starting, lighting, and ignition batteries) has been devoted to increasing energy storage capacity, specifically aimed at straight electric-vehicle applications. The hybrid electric vehicle, however, has need for batteries with a higher power to energy ratio than does the straight electric vehicle.

Relatively little electrical energy needs to be stored on board the hybrid vehicles compared with the electric vehicles. Consequently, there are several candidate batteries that could likely provide the required energy and power for application in hybrid vehicles. The lead-acid battery has the advantage of being much more near term but, in spite of the considerable efforts that have been put into its development, it still has relatively lower energy density than some of the other candidates, and there are cycle-life limitations that are likely to persist. Thus, the lead-acid battery is a high-cost option. The lithium-ion and lithium-polymer batteries are leading candidates from the standpoint of cost and energy density. However, there are critical issues to be resolved, especially those concerning the manufacturing process, achieving high cycle life, and obtaining appropriate thin electrodes to achieve the high power outputs. The nickel-metal hydride battery is also a candidate, but has unresolved cost, cycle life and efficiency problems. Unless major breakthroughs are obtained within the next two years, nickel-cadmium batteries will probably be eliminated due mainly to higher cost and environmental concerns, and zinc-air batteries may be eliminated due to power-density limitations. The more promising battery technologies appear to have been selected by PNGV from a longer list, which includes such past candidates as nickel-iron, nickel-zinc, zinc-chlorine, zinc-bromine, and the like. In the committee's view the best technologies are probably being considered by the PNGV for the hybrid vehicles, but no specific justifications were presented for their selection.

Batteries represent an important component of a hybrid system, but it was not clear to the committee that sufficient effort is being put into battery research by the PNGV. The FY 1996 expenditure of less than $10 million seems modest in light of the overall technical problems to be resolved and the amount of funding that has been put into high energy batteries in the past. If the characteristics of the lithium and nickel-metal hydride batteries are as promising as they initially appear, it would be worthwhile for PNGV to focus the research efforts and funds on the critical problems to be resolved.

Flywheels

Flywheels represent an alternative to batteries as energy-storage devices and, in some aspects, have characteristics superior to batteries. In particular, they have the capability for very high power to weight, both in delivering power and, perhaps more importantly, in accepting power. The energy-storage capacity per unit weight and volume of flywheels makes it impractical to use them as the primary source of motive energy in a car. As a result, for the hybrid vehicle configurations, which might be loosely classified as either (1) range-extender hybrids, (2) dual mode, or (3) power-assist hybrids,[4] the flywheel is viewed as having potential only for the power-assist configuration. In this type of use, flywheels have very attractive power to weight and power-per-volume characteristics. Their performance is only marginal or fair with regard to other important characteristics, such as efficiency and self-discharge, and they currently present potential safety containment and cost concerns.

Flywheel safety requires fracture-energy management in case of failure. From both a consumer acceptance and a product liability standpoint, it may be necessary for vehicle manufacturers to make flywheels "fracture proof," that is, to eliminate the possibility they could come apart in a catastrophic fashion. The cost concern is associated with the high-cost of lightweight composite materials and the manufacturing process for flywheels using such materials.

Other issues of concern are potential gyroscopic effects coming from shock loading, self-discharge on the order of one-half of one percent per hour of stored energy, and long-term durability. There are also appreciable challenges, as yet unsolved, regarding the appropriate matching of alternator and flywheel design, electrical safety, maintainability of the system, and providing adequate and appropriate cooling (Energy Storage for the Next Generation Vehicle, 1995).

Ultracapacitors

Ultracapacitors are in the same category as flywheels, being compatible only with the power-assist type of hybrid-vehicle configuration. They have also been proposed as a way to limit the surge current load on batteries used in hybrid vehicles. Problems identified thus far by PNGV concern energy density, cost, and self-discharge characteristics of ultracapacitors. Energy storage is limited, probably to less than 2 kWh, and there are, additionally, problems of energy input and output. Power electronic conditioning can be applied to manage the charge and discharge cycles efficiently, but at a cost. A potential hazard is unbalanced current flow between individual cells in the ultracapacitor stack, which has unknown safety implications. This is an area where there is very little, if any, available data.

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[4] Hybrid vehicle configurations are defined as follows: (1) Range extender—the engine (or fuel cell) provides only the average power needed to keep the electric storage system charged for normal operations; (2) dual mode—the engine (or flywheel or fuel cell) is sized so that either it or the electric-storage system may be used to provide the entire power needs of the vehicle; (3) power assist—the electric power system (battery or fuel cell) is assisted in providing peak power requirements by another energy source (battery or flywheel).

On the other hand, recent laboratory demonstrations of individual cells have indicated superior performance. Using carbon-based materials, devices have shown energy and power densities of 10 Wh/kg and 2 kW/kg, with 90 percent turnaround efficiency and 100,000 cycle lifetime—all of which exceed the PNGV performance targets for this technology. Metal oxide ceramic device costs are now in the range of $100 per kJ, and the cost goal is about $1 per kJ. Presently, the leakage or self-discharge of such units is about 10 $\mu A/cm^2$ compared with a PNGV target of two orders of magnitude lower. Clearly, substantial progress has been made; but key challenges remain, and ultracapacitor developments deserve additional coordination efforts from the PNGV management.

Electrical and Electronic Power Conversion Devices

This effort at PNGV is focused on the electric power conversion subsystems to be used with propulsion systems for hybrid vehicles. Key elements being considered are the electric motor/alternator, the electric power inverter, and the electronic/electric controllers. Also being addressed are the adjustable-speed drives required for vehicle subsystems, such as electric power steering, passenger compartment heating, ventilating and air conditioning, and other vehicle accessories.

The committee noted that the technical team responsible for this area has shown good awareness of the state of the art for these devices and has established appropriate and challenging targets for performance, efficiency, weight, and cost, as given in the Technical Roadmap. Overall size targets have not been established, but these are highly dependent upon the vehicle configuration chosen. Realistic size and shape targets can only be derived from specific packaging studies. The milestones in the PNGV Technical Roadmap show the overall electric driveline efficiency improving from 70 percent to 85 percent in 10 years, and its weight decreasing by 47 percent. The electronic inverter/controller cost must be reduced by 90 percent, and the electric motor cost by 80 percent. In the committee's view these are very demanding challenges.

The schedule in the PNGV Technical Roadmap indicates a need for design and evaluation of three generations of hardware. Baseline knowledge in this area is derived from several extensive electric-vehicle programs within Chrysler, Ford, and General Motors over past decades, as well as from work on numerous electrical and electronic control systems developed by the U.S. government for military and space applications. Progress under the PNGV program, to date, largely has been related to work performed under the DOE hybrid electric vehicle projects, but the Technical Roadmap targets several additional government agencies and other research programs for support of the developments needed for the PNGV Goal 3 vehicle. The challenge will be to coordinate these efforts such that they address the unique automotive requirements and focus on cost reduction as a primary target. In addition, this program faces a major challenge to develop electrical and electronic components suitable for the wide variety of powertrain configurations currently being considered by the PNGV. The absence of complete systems studies for many of these configurations compounds this challenge. As these studies become available and the technology focus narrows, the development of appropriate electrical and electronic components capable of overcoming the significant technology and cost barriers outlined in the Technical Roadmap can be managed more effectively.

LIKELIHOOD OF MEETING GOAL 3 POWERTRAIN NEEDS

The challenge of meeting three times today's fuel economy in a prototype vehicle ready for production in 2004 (with all of the other requirements surrounding Goal 3) is, in the committee's view, extremely difficult. Clearly, recent reductions in funding for the government portion of the program increase the risk that this target will not be met within the schedule as currently specified. Nevertheless, significant progress is being made by the PNGV.

Powertrain improvement is crucial for the program's success. The DICI engine is probably the only candidate today that could be combined with a conventional drivetrain and other vehicle changes and come close to meeting Goal 3 within the PNGV schedule. Hybrid configurations improve the likelihood of meeting powertrain efficiency targets but increase the challenges relative to size, weight, and cost. Gas turbine and Stirling engines are candidates only in conjunction with a hybrid powertrain, not as stand-alone prime movers. In addition, each engine has its own specific technical challenges that must be met for it to continue as a candidate past the 1997 technology selection date. Fuel cells offer the greatest long-term potential fuel economy gain, with by far the most aggressive improvements required, and have demonstrated substantial progress over the past few years. Each of the various energy-storage and electrical-conversion devices being considered for hybrid powertrains faces very difficult size, weight, efficiency, and cost hurdles.

It was observed at the recent PNGV energy-storage meeting that there has been relatively little improvement in the past year on the critical issues of safety and cost and that there is a lack of coordination, which hampers progress. If this is true, this situation must be corrected for adequate information to be available for proper choices to be made in 1997.

The PNGV program plan calls for technology selections to be made at the end of 1997 so that concept vehicles can be built using the most promising systems. Completion of more rigorous systems analyses before then will help in this selection process, but it is likely that these decisions still will have to be made on a largely subjective basis. The committee continues to believe that this selection process should designate some of these technologies as being worthy of continued support but should recognize that they are outside of the time frame of the PNGV program.

RECOMMENDATIONS

Recommendation. The PNGV should devote substantial additional resources to the DICI hybrid powertrain in view of its relatively high potential to meet PNGV Goal 3 objectives.

Recommendation. The PNGV should develop a powertrain systems analysis methodology to aid in the evaluation of the potential gains and probability of success for various technologies.

Recommendation. The PNGV should perform vehicle packaging studies soon for each powertrain system that is likely to remain a candidate past 1997. Such studies would establish realistic size and shape goals for the component development programs.

Recommendation. The PNGV should perform a study to establish the energy balance, in-use environmental effects, and resource requirements, as well as production and distribution costs, for any fuels other than gasoline or diesel fuel being considered for use in Goal 3 vehicles.

Recommendation. PNGV should continue to develop flywheel and generator technologies.

Recommendation. On a stand-alone basis, batteries still appear to be the best near-term candidates for energy storage, and PNGV should fund development of the most promising battery system consistent with this potential.

Recommendation. PNGV should focus its ultracapacitor R&D on the most promising technologies, and serious efforts should be devoted to the investigation of a battery/ultracapacitor hybrid storage device.

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7

Infrastructure

The United States enjoys the world's most effective and extensive road transportation system. Over 175 million passenger cars and light trucks travel more than two billion miles annually on the 3.9 million miles of public roads in the United States (NHTSA 1995; FHWA 1994). About one in ten members of the U.S. workforce is engaged in some aspect of the road transportation sector (ETF, 1994). Manufacturing and service industries, and associated large and small businesses, have invested hundreds of billions of dollars to form a vast transportation-related infrastructure. This infrastructure encompasses activities associated with vehicle production, insurance, maintenance, repair, and recycling together with fuel production, distribution and retailing. The total highway transportation infrastructure encompasses these private investments and workforces as well as the entire public highway system with its support workforce and its environment.

Some extremely attractive technologies under consideration for PNGV have the potential to introduce large changes in the demands on the infrastructure, which will result in requirements for new capital, labor, and natural resources. The extent of these changes will vary widely, depending on the body and structural materials, the powerplant and the energy-storage system.

INFRASTRUCTURE IMPLICATIONS OF PNGV TECHNOLOGIES

The vehicle production infrastructure includes not only the OEMs but also a vast materials and parts supply base. PNGV technology could introduce profound changes in the vehicle-related industries. For example, a shift from steel to aluminum or composites would alter capital and labor needs among the materials production and forming industries. The maintenance, crash repair and recycling industries would require additional investments in capital equipment and training to handle new materials. Automobile insurance costs are likely to be influenced by changes in these service industries and by the design and repairability of the PNGV vehicle.

The adoption of alternative PNGV power plants that use fuels such as methanol, dimethyl ether or hydrogen would create immense demands on the entire fuel production, transportation, storage, and retail-distribution infrastructure. Significant new investments would be required both in the production and retail segments. Portions of existing facilities and equipment could become obsolete, resulting in the early writeoff of investments. The willingness of consumers to adapt to the use of alternative fuels will also have an important influence on the success of the PNGV program.

The highway infrastructure includes the highway system, the vehicle and its operator, and the services associated with vehicle operation. The operation of vehicles produces the undesirable consequences of property damage, human casualties, and environmentally harmful emissions. A number of significant issues relating to PNGV arise from highway infrastructure considerations.

Today's highway designs are predicated on existing interrelationships among the vehicles, the operators, the highway, and the operating environment and have evolved over a period of about 100 years. Any major change in the vehicle and its attributes requires an understanding of possible ramifications for existing relationships. Obvious examples include the compatibility of breakaway roadway sign supports and the crash characteristics of vehicles constructed with lightweight materials in support of occupant crash protection strategies. Similarly, new hazards from toxic substances, electrical discharges, and high momentum rotating devices will require special skills by emergency response personnel during crash rescue and when clearing and disposing of crash debris.

There is a large base of knowledge and experience from owning and operating current vehicles. Any major change in the vehicle dynamic response or vehicle-operator interaction will require adaption by vehicle operators. Changes in vehicle dynamic response, vehicle maintenance, safety precautions, and fuel handling procedures all could require behavior modifications that may impact the operator's acceptance of a PNGV-type vehicle.

The operating environment of the vehicle/highway system poses numerous issues to the PNGV. These issues include both regulated and unregulated emissions, road and vehicle noise, and highway runoff. Any changes that impact environmental quality need careful analysis. In reducing regulated highway emissions, due attention must be given to the total environmental impact, including in-use emissions and energy consumption in fuel production and distribution.

SAFETY

The influence of the PNGV on the safety of the vehicle/highway system is another issue that requires consideration. During the 1990s the marketing of vehicle safety equipment such as inflatable restraint systems (air bags) and anti-lock braking systems has heightened public awareness of highway safety. According to a 1992 study, "recent trends in consumer preference for passenger cars with air bags, and vehicles with good safety records, suggests a major shift in the public's concern for safety" (NRC, 1992). The safety issues associated with the PNGV go well beyond simply meeting today's Federal Motor Vehicle Safety Standards. There is extensive public information that equates reduced vehicle weight to reduced safety (OTA, 1995). The large weight reduction achieved in the PNGV vehicle may foster the perception that occupant safety is significantly reduced and result in poor acceptance of PNGV-type vehicles by consumers, even though the minimum safety standards are met.

PNGV ACTIVITIES

The present statement of Goal 3 safety is as follows: "The target vehicles will meet the efficiency improvement goal while meeting present and future Federal Motor Vehicle Safety Standards" (PNGV, 1995). The industry studies presented to the committee did not include any safety considerations beyond meeting present federal standards. The committee noted that the DOT has had minimum participation in the PNGV program and that no research has been identified to develop future standards to specifically address PNGV technology safety concerns. Further, the committee noted that the U.S. Environmental Protection Agency also has had minimum participation in the PNGV program and has not identified research to develop future standards addressing emissions concerns for new PNGV technologies.

The committee was briefed by the PNGV on a preliminary study entitled "Infrastructure and Capital Needs Assessment." A research team from the Argonne National Laboratory and the Oak Ridge National Laboratory discussed first-order effects of PNGV technologies on fuel demand and capital requirements for manufacturing. Studies to assess fuel production and distribution impacts and to estimate fuel-cycle CO_2 emissions were stated to be underway, but they were not presented to the committee. The researchers indicated that the general impacts of adopting alternative technologies are known by the PNGV team but that systems analysis is needed to provide additional insights and quantitative results. As discussed in chapter 8, no systems analysis or infrastructure modeling results are currently available.

The committee commends the PNGV on its preliminary infrastructure study and notes that the assessment of the total energy consumption and fuel-cycle CO_2 emissions for each PNGV power system alternative will be valuable in comparing each technology on a total-energy-use basis.

The Intelligent Transportation System (ITS) program at DOT is an important national initiative that presents an opportunity for enhancing PNGV safety. Several ITS systems are planned for active deployment within the PNGV timeframe. The committee believes that increased interaction between the PNGV and ITS programs would be beneficial.

ISSUES

The technologies under consideration for the PNGV have the potential to induce large transformations in the highway-vehicle-fuel supply infrastructure. Extensive shifts in requirements for capital labor and natural resources could result. In the absence of detailed analysis, it is not clear that all technology scenarios would lead to the objectives of increased competitiveness, reduced dependency of foreign sources of energy, and lower energy consumption and environmental pollution. The committee identified a need to address considerations associated with infrastructure as an integral part of the PNGV program, concurrent with decisions regarding technology selection. Issues include capital requirements, shifts in employment, global economics of energy and materials production, vehicle safety requirements, total cost of vehicle operation (including insurance and maintenance), and total environmental consequences. Some of the potential infrastructure changes induced by PNGV technology could adversely affect overall U.S. competitiveness, unless the broad resource and infrastructure issues are recognized and resolved. Continuing careful assessment of the infrastructure issues of alternative technologies is an essential part of the technology selection process for the PNGV.

The application of PNGV technologies will introduce a myriad of safety and other issues dealing with lightweight materials, energy-storage and conversion systems, and alternative fuels. For example, new questions relating to recycling of materials or vehicle designs to provide PNGV owners the same safety level as the owners of competing conventional vehicles were not defined at the time of this review. The stark absence of active participation by DOT in addressing and resolving PNGV transportation policy and safety issues is of concern to the committee. Early involvement of the National Highway Traffic Safety Administration would be beneficial since future federal standards relating to Goal 3 vehicles may be anticipated.

RECOMMENDATIONS

> **Recommendation**. The PNGV must continue to address infrastructure issues as an integral part of its program. A careful assessment of infrastructure issues associated with alternative technologies should be an essential part of the technology selection process scheduled for 1997.
>
> **Recommendation**. The PNGV should immediately involve DOT's National Highway Traffic Safety Administration in addressing and resolving the safety issues raised by Goal 3 vehicles.

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8

Systems Analysis

Based on its understanding of the PNGV technical organization structure and Technical Roadmap (see chapter 9 for further discussion), the committee considers that vehicle systems analysis and modeling as defined in the road map are mandatory to:

- guide the technology teams in their research and development efforts and assure that all assumed metrics are optimized to the overall vehicle requirements
- provide the Vehicle Engineering Team with a means to make tradeoff studies between contender subsystems and components and to determine the minimum acceptable performance parameters for competing technologies
- objectively optimize selected subsystems and systems to meet performance requirements with minimum fuel consumption

The PNGV organization concluded at a USCAR/government modeling conference in November 1994 that the system analysis tools available are inadequate for the PNGV challenge. It was decided that a qualified contractor, capable of performing systems analysis and modeling was a vital requirement. After screening potential contractors, one was preliminarily selected in early 1995. Unfortunately, funding was delayed, other circumstances required a change of contractors to be made, and the contract award was not made until late October 1995. This delay of approximately one year could seriously impact the technology selection process and the 1997 milestone.

Other systems analysis projects have been identified, including analysis and design, improved subsystem models, integration models, and system analysis support. None of these projects has as yet been funded. As a result, the number of PNGV personnel working in the critical systems analysis area appears to be negligible.

The timely use of systems analysis to guide development is a critical issue for PNGV management to resolve. The timing presented in the Technical Roadmap for systems analysis efforts has been seriously delayed. The Technical Roadmap, in Section IIIA, clearly states:

> The role of systems analysis in the PNGV is to support component, systems, and vehicle development by providing the analytical capability to efficiently and accurately assess competing

> technologies, and vehicle concepts against Goal 3 objectives and vehicle performance requirements. This will enable an objective evaluation of risk, benefit, and cost, in order to focus on the best options, with the least expenditure of resources.

This statement implies that the selection of optimal technologies for the design, fabrication, and assembly of the concept vehicles would be adversely affected by the absence, or inadequacy, of supporting subsystem and component tradeoff studies. These studies, in turn, depend on the availability of appropriate systems analysis methods.

Another important issue is the selection of the best system architecture for the concept vehicle. This is being approached on two fronts. As noted earlier, Chrysler, Ford, and General Motors have decided to carry on separate PNGV concept vehicle development in each of their respective engineering organizations. It has also been decided that the PNGV will not design and build a concept car. This is logical, if viewed from a proprietary-product standpoint and in terms of resource optimization. Each company will be using its in-house systems analysis and modeling capability to support its design selection. Although the PNGV team does plan to perform system analysis and vehicle engineering, the scope and specificity of the analysis must be designed with full understanding that the input from each automotive manufacturer may be vague in content. Each manufacturer is obliged to meet the same set of challenging requirements (specifications) for the Goal 3 vehicle. In the view of the committee, without a rigorous and disciplined systems analysis effort, the common requirements cannot be effectively established in a timely and coordinated fashion. Thus, the committee identifed the systems analysis effort as imperative. In addition, the committee considers that this effort would be most effectively directed and managed by a USCAR technical director.

The PNGV technology teams need direction on vehicle system requirements, and this should be provided by PNGV Vehicle Engineering Team, supported by systems analysis. This approach provides a single conduit for design information and design tradeoffs during the pre-competitive phase of the program. Vehicle system, subsystems, and component models will be created, which will support both the PNGV technology teams and the individual company vehicle teams. It would be helpful to the program if the USCAR partners provided their in-house systems models to the PNGV to the extent appropriate. This action would help accelerate the systems analysis activity and make up for lost time.

The PNGV Vehicle Engineering Team must identify all of the breakthrough technology requirements for each of the subsystems under consideration. Technology evaluation and selection will be accomplished by both the PNGV Vehicle Engineering Team and the individual companies. It is not clear to the committee, based on the information it has received, specifically how the tradeoffs among subsystems will be accomplished. Some vehicle target metrics have been established; others still require definition; and others will probably require updating. There also must be an appropriate definition of metrics for each subsystem, driven by the system specifications.

The committee concluded that there are significant barriers to the accomplishment of the systems analysis and vehicle engineering tasks necessary to achieve the PNGV goals. While the technical teams for system analysis and vehicle engineering have been identified, along with an overall plan, very little has been accomplished because of a lack of funding and the delay in selecting an appropriate contractor to develop appropriate system, subsystem, and component models. Approximately 18 months remain before selected-vehicle system architectures must be quantitatively defined with metrics to allow the final selection of the concept vehicle architecture. To this end, tradeoff studies of all potentially relevant configurations are essential. Such studies may incorporate information relevant to market-based assessments of attractive technologies. Within the PNGV there does not appear to be complete awareness of the composite state of the art of the competing technologies, nor are the best models and simulation codes for these technologies available.

In the committee's view, there is a clear need for focused, central leadership to coordinate the technical teams and address overall vehicle requirements. A single USCAR Technical Director would be well positioned to lead the systems analysis and vehicle engineering efforts and to establish priorities for the subsystem technical teams.

RECOMMENDATIONS

Recommendation. The PNGV should assess the impact on the overall program schedule of the delay in implementing systems analysis and vehicle engineering tasks, and the need for remedial action. Priority projects must be identified and implemented by the technical teams as soon as possible.

Recommendation. The PNGV should formalize subsystem evaluation and selection process without delay, and performance criteria should be provided to the PNGV technology teams. The systems analysis must be an iterative process that continually receives new information, updates models, and provides updated results from optimizations and tradeoff studies to system, subsystem, and component designers.

Recommendation. Overall vehicle system and subsystem analysis driving component developments should be under the control of a USCAR technical director.

9

Program Organization and Management

Management of the PNGV program represents a major challenge, requiring technological innovation, integration of complex elements, minimum product cost, high product reliability, environmental protection, passenger safety, and enhanced competitiveness. The involvement of the three major U.S. automotive companies—Chrysler, Ford, and General Motors—which are traditionally competitors rather than collaborators, together with several government agencies and national laboratories adds an additional major challenge. While national efforts involving many partners are not without precedent (e.g., Sematech), the goal of producing a commercially viable product capable of enhancing U.S. competitiveness in international markets while meeting anticipated domestic market requirements sets the PNGV effort apart from other initiatives. The committee considers the underlying concept of the PNGV program to be credible. The objective of the program is to reassert U.S. leadership and enhance the competitiveness of U.S. industry in the technology-driven global automotive market.

This chapter addresses PNGV program organization and management. Progress made in these areas since the first peer review is assessed, and suggestions are made for further improvements. A final section on foreign technology puts the PNGV program in the broader context of efforts to develop and implement advanced vehicle technologies by other countries in competition with the United States. It highlights the likely challenges that confront PNGV vehicles both in international markets and in the domestic market from vehicles imported into the United States.

PNGV TECHNICAL ROADMAP

The draft PNGV Technical Roadmap provided to the committee prior to its meeting in August 1995 answers many of the questions posed during the previous review (PNGV, 1995b). Of particular note in that review was the need for a more detailed program plan outlining objectives, task descriptions, management responsibilities, milestones, resources, schedule, and performance metrics. The Technical Roadmap is recognized by the committee as a constructive beginning and an important achievement in 1995. However, the committee continues to have concerns as follows:

- The process of selecting technology concepts for evaluation, the selection of concepts for vehicle application, and the technical management to assure that vehicle performance objectives and timing are met are not clearly defined in the Technical Roadmap.
- The technical teams (e.g. on fuel cells) appear to be effectively organized and working to specific objectives. However, problems exist with (1) overall vehicle planning and control; (2) the process for program review against specific targets and milestones in the technology development plan; and (3) the process for technology "downselect" in 1997. Further, federal budgets pertinent to PNGV are not allocated as line items, and it is difficult to make judgments about relative spending levels and appropriate resource allocations.
- A procedure is required for defining metrics for subsystem performance and then effectively communicating these requirements to the technology teams. The committee is concerned that these matters appear to have been handled on an ad-hoc basis. Unless this issue is properly addressed, overall program goals could be severely compromised. Initiation of the systems analysis effort will undoubtedly help, particularly if placed under the direction of the recommended USCAR PNGV Technical Director. Specific actions to remedy these deficiencies are recommended by the committee as a matter of some urgency, as discussed below.

TECHNICAL ORGANIZATION STRUCTURE

During the past year, the PNGV has solidified its technical organization structure, which is illustrated in figure 9-1. Central to the organization are the technical teams responsible for R&D on candidate subsystems; namely, the manufacturing, materials and structures, and systems analysis teams. Technical oversight and coordination are provided by the Vehicle Engineering Team. The teams are staffed by representatives from government and industry. The committee determined that these teams appear to be effectively organized and working towards specific objectives. Many of the technology teams were established in 1995 and have held a number of meetings. Their efforts have lead to a first round of development targets in each of the technology areas; these targets provide importance guidance for the various government-sponsored projects in the PNGV program. However, the committee was concerned that some key management personnel from USCAR are spending only a very limited amount of time on PNGV activities.

In its Phase 1 report the committee recognized that each of the three automotive companies might "independently want to pursue applications of the technologies developed as part of Goal 3" (NRC, 1994). While not suggesting that this approach was inappropriate, the committee noted that "the overall objectives of Goal 3 must be managed by a single platform team." The committee futher observed that, although separate industry teams "would have full access to the technologies developed as part of Goal 3, the co-located USCAR team would have

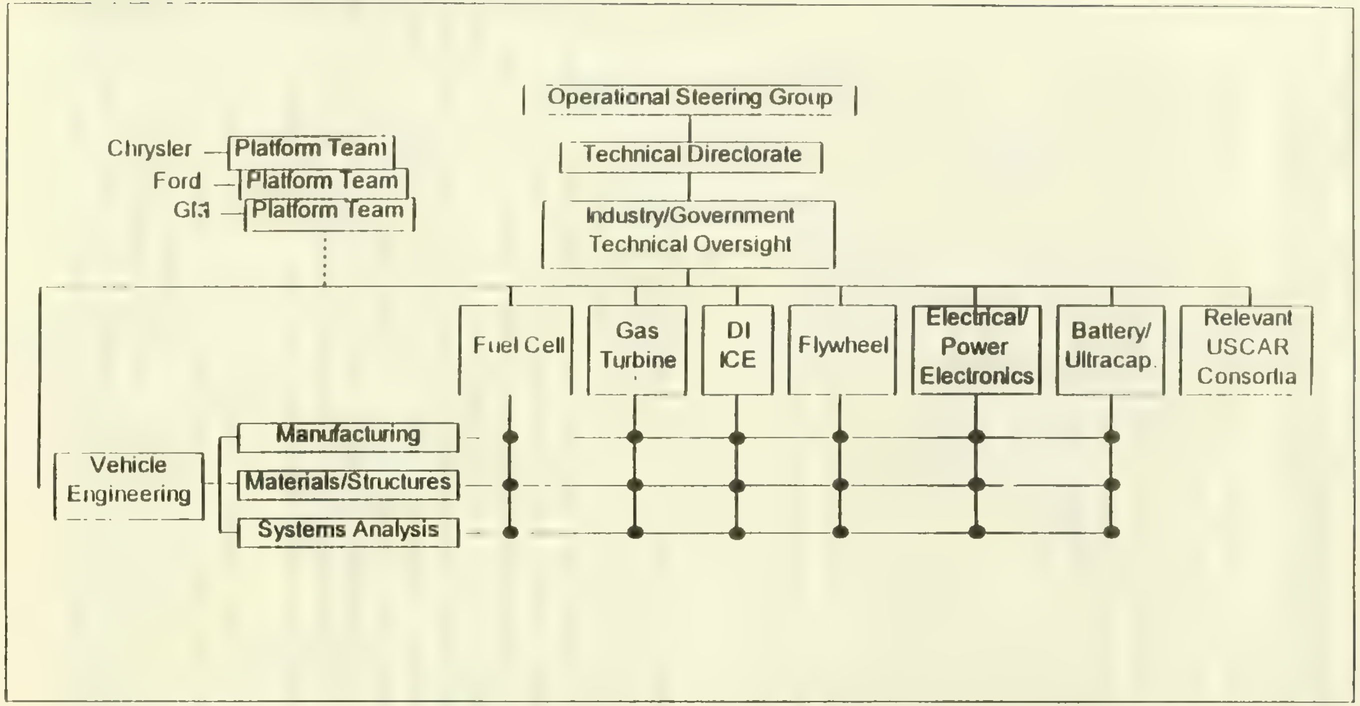

FIGURE 9-1 PNGV Technical Organizational Structure. (Note: Matrix organization with each node representing interaction among teams.)

* DI ICE = direct injection internal combustion engine

SOURCE: PNGV, 1995a.

the full authority and responsibility to set the direction for meeting the objectives of Goal 3." Chrysler, Ford, and General Motors, in concert with PNGV, recently decided not to develop a single PNGV concept car but rather to have each company pursue its own concept car (or cars), sharing directions and decisions as appropriate. The committee notes that this decision impacts many aspects of the program plan and management, as follows:

- The PNGV Technical Roadmap must help assure that there is close coordination between the work of the PNGV technical teams and the needs of the individual automotive manufacturers.
- A central systems-analysis function is more imperative to analyze tradeoffs and to help refine subsystem targets, but each company must now supplement the central systems analysis activity with its own more specific needs.
- The need for a USCAR technical director still appears paramount to plan and execute the systems analysis and tradeoff studies (despite a very late start); establish the principal specifications for the Goal 3 vehicle(s); and provide the broad architecture and foundations for the vehicle subsystem and component design and engineering, which must be established in less than two years to meet the 1997 milestone for technology selection for the concept vehicle. A further essential role of a USCAR technical director is to provide unified technical and program guidance to the government organizations supporting the PNGV program.
- It is not imperative for USCAR per se to have a central, integrated platform team guiding the program. Rather, each of the three car companies must now manage its own internal operations so as to develop their own concept car designs, and each must accordingly provide feedback to the PNGV program, including the government participants, on the innovations that each needs. Nonetheless, at some point a USCAR technical director needs to establish the priorities of demands placed on PNGV by the individual car companies. There will be a premium on good communications between the parties so that government-sponsored projects can have the highest probability of providing the essential technology.
- Rather than PNGV being managed as a single-line, single-focus program, it now becomes a less cohesive assembly of individual projects aiming to satisfy the needs of three different project teams. The management challenges are daunting, and the potential economic benefits of joint USCAR developments are perhaps being diluted.

SCHEDULE AND RESOURCES

The Technical Roadmap includes an overall program schedule as well as schedules for the various technology teams. All the schedules appear to be in line with program objectives as would be expected for a roadmap is in its infancy. Among many challenges to meeting the overall schedule, perhaps the greatest are the long delay in starting the systems analysis effort and the reductions in requested government FY 1996 funding. As discussed above, the committee considered the delay in starting systems analysis to be extremely unfortunate, particularly since the reasons for the delay did not appear insurmountable. The lack of systems feedback to the technology teams means that they do not fully appreciate the system sensitivity or the importance of their various technical targets—a problem that threatens the schedule. At this time the overall impact of the systems analysis delay on the schedule cannot be estimated.

A major issue of concern to the committee is the level of funding for the government part of the PNGV program. The PNGV program plan included estimates of required government funding levels, which were to grow over time. These levels were considered essential to program success and were based, in part, on the expectation that the government partners would fund longer term, higher risk technologies; the industry partners would fund shorter term, lower risk technologies. FY 1996 was the first year that PNGV program management was able to address the government PNGV budget (comprising activities at federal agencies) in a relatively cohesive fashion. The FY 1995 budget was already finalized and/or working its way through the Congress when the PNGV program was initiated.

It is now known that the FY 1996 federal budget has been dramatically altered by changes in federal government priorities.The budgets for the various federal PNGV programs have been reduced below those requested. Because the final PNGV budgets were not known when this report was prepared, the committee was unable to judge the impact of the reductions on the overall PNGV schedule. Without question, the budget reductions will delay milestone achievement and increase the risk associated with meeting the technical objectives, unless a reallocation of resources to the most promising candidate subsystems occurs within the PNGV program. The problem is compounded by the fact that the government program manager does not have the authority to redeploy existing funds to the highest priority projects. When the budgets are finalized and the Technical Roadmap updated, the overall program schedule and associated risk will need to be reassessed in light of the original program goals.

The committee was also concerned that information is not available on the level of resources devoted to the PNGV program by the USCAR partners.

PROGRAM MANAGEMENT

As noted earlier in this report, the committee continues to believe that, with respect to detailed program management, the industry partners would be well served by having a single technical director in USCAR, as recommended in the Phase 1 report. The absence of such technical leadership has resulted in the USCAR members of the PNGV being unable to use the leverage of an integrated organization in pursuit of the program goals. Many of the current program difficulties—the delay in starting systems analysis work, the complexities resulting from the decision to develop separate concept vehicles, and the very limited amount of time being spent on USCAR/PNGV business by some staff—could all be addressed more effectively if the USCAR members of the PNGV formed an integrated working group under a single technical director, rather than being a team in name only. The responsibilities of a USCAR technical director would include estabilishing appropriate operating procedures and control mechanisms.

On the government side, the committee continues to consider strong central program management essential to the success of the program. The government currently lacks an effective program management organization and is also in need of a chief technical officer to provide direction and leadership to the many federal organizations supporting PNGV.[1] The program management office, located in the DOC, operates more as an information office than as a program director's office. The staff of the program management office have essentially no authority to impact the federal program other than through personal persuasion. PNGV management at the DOE similarly is not empowered to directly influence the array of federal projects potentially contributing to the PNGV initiative. The majority of these projects were initiated before the advent of the PNGV program and, therefore, respond in varying degrees to PNGV needs.

One result of this management arrangement is that, when the technology selection occurs in 1997, PNGV management on the government side will have little or no ability to participate actively in that process or to redeploy funds from less significant projects to more important ones. Consequently, high priority projects may not be adequately funded, and projects of less relevance to PNGV, albeit possibly justified for other purposes, may be funded.

FOREIGN TECHNOLOGY

At its October meeting the committee was briefed by representatives of some foreign organizations and was provided an overview of overseas programs based on broadly available information (see appendix B). The U.S. PNGV activity appears to have stimulated reactions in Europe and Japan, which have recently established aggressive, well-funded advanced vehicle development programs in response to the U.S. initiative. Having effectively set a new target for international competitiveness, the United States can ill afford to reduce its efforts and commitment to PNGV. If it were to do so, the U.S. automobile industry would likely have its international competitiveness significantly damaged in the mid- to long-term.

Some significant examples of foreign leadership are as follows:

- Audi is now producing an aluminum body automobile for general sale. This provides Audi with an advantage in the development of such lightweight vehicles.
- The Europeans are ahead of other countries in diesel engine automobiles, having produced and sold them for many years in response to market demands in Europe. These demands were spurred by differing diesel fuel pricing and emissions standards than in the United States.

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[1] The committee specifically chose not to address the issue of where the central government focus should reside, since many of the determining factors are beyond the scope of the committee's task.

- The Japanese lead the world in lightweight, high-efficiency, spark-ignited engines.
- In gas turbines for hybrid vehicle application, no leader is obvious.
- The Germans have a strong fuel cell development program.
- The Japanese have commericialized ultracapacitors.

These evaluations must be considered to be preliminary. However, the committee believes—on the basis of the information provided—that the United States is not in a leadership position in many of the technologies critical for a successful PNGV (table 9-1). This puts the United States at a disadvantage that may be significant and argues strongly for an appropriately funded federal and private PNGV program.

TABLE 9-1 Preliminary Ranking of U.S., European, and Japanese Advanced Automotive Technologies

Technology	U.S.	Europe	Japan
Internal combustion, compression ignition engine	3	1	2
Internal combustion, spark ignition engine	2	2	1
Gas turbine	1 (systems).	1 (systems)	1 (components)
Fuel cell	Immature technology—no ratings assigned		
Flywheel	1	1	3
Battery	1 (high energy)	2	1 (high power)
Ultracapacitor	3	3	1
Lightweight materials	2	1 (aluminum)	1 (high-strength steel)

Note: 1 = highest ranking; 3 = lowest ranking

PEER REVIEWS OF THE PNGV

Finally, the PNGV plan does not show regular program reviews either by the participants or through independent reviews. The NRC committee's first report on the PNGV research program was issued in October 1994 (NRC, 1994) and was acknowledged as "extremely valuable to the project for its ability to provide unbiased, constructive suggestions for improvement" (The White House, 1994). The committee suggests that regular program reviews be explicitly scheduled and that an appropriate budget be earmarked for this purpose.

RECOMMENDATIONS

Recommendation. The committee still strongly recommends that the partners in USCAR appoint a single technical director as a way of benefitting from the leverage of an integrated organization in pursuit of PNGV goals.

Recommendation. The committee reiterates its earlier recommendation that senior management at DOC and DOE install a management structure with appropriate authority and responsibility as soon as possible and ensure strong, capable staffing. This structure should include a chief technical officer to provide technical direction to the wide array of government technical activities. The role of the chief technical officer becomes even more critical in the absence of a single USCAR techncial program director.

Recommendation. The PNGV needs to have a better calibration of the state of development and predictions for commercial availability of foreign technology.

Recommendation. As a matter of urgency and in accordance with the committee's recommendation in its first report, the PNGV should conduct more comprehensive assessments and benchmark foreign technology developments relevant to the program. If warranted by the results of such analyses, PNGV should reassess its research priorities.

Recommendation. To be successful, a complex development program such as PNGV must have well defined plans and objectives, adequate resources, and the support of sufficient funding. It is incumbent upon both USCAR and the government to ensure that adequate resources for the PNGV program are provided in a timely manner and used efficiently in overcoming the critical barriers to achieving PNGV goals.

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10

National Commitment

Given the ambitious scope of the PNGV program and its decade-long schedule, sustained commitment is needed for success. Significant benefits can be anticipated from the program; notably, in economic competitiveness, increased national security, and improved environmental quality. These benefits will, however, accrue over a long period of time and be widely distributed. For these reasons it is unlikely that any group of constituents will be drawn to develop and sustain support for the program, particularly in the absence of a compelling economic reason to do so. Therefore, the PNGV has an important role to play in building national commitment for the program. The DOC's PNGV program office has made significant progress in this regard over the past year, expanding its outreach and building support across a number of constituencies. Information presented to the committee at its meeting in Dearborn, Michigan, in August 1995 indicated that USCAR has also made a concerted effort to inform Congress and the public about this program.

In the view of the committee, a project of this magnitude and complexity requires sustained public support—based, in part, on tangible results—to succeed. Capturing the public's interest in new technologies to meet future individual driving needs involves establishing public expectations. The committee offers some suggestions for means by which this might be achieved.

Perhaps most significantly, the industry partners of the PNGV are well positioned to build public support for this project through advertising. Showcasing the PNGV vehicle—a highly efficient, environmentally friendly car—and its successful development through the duration of the program in a wide array of venues from automobile shows to television to print has potential for increasing public support for the project and developing a market for the ultimate products.

PNGV has undertaken a media education effort to build national commitment for the program. The committee commends this response to the recommendation regarding national committment in the Phase 1 report. An ongoing challenge will be to obtain credit for significant innovations that may be perceived as only loosely associated with the PNGV. A number of channels are being pursued through print and video communications. One such means to educate the media and others is USCAR's publication *Dateline 2000*. This publication might feature the PNGV in each issue and continue to be circulated to key federal, state, and local policy makers, schools, and universities, as well as to media outlets and suppliers, to build their support and involvement in the project. Another means of media education rests with the government partners. To date, only DOC has pursued media attention in PNGV activities. However, the DOE is the largest participant in terms of research projects, followed by the National Science Foundation (NSF). In the committee's view, increased commitment and visible participation of all the government partners (especially DOE, NSF, DOD, DOT, NASA, the U.S. Department of the Interior, and the U.S. Environmental Protection Agency) is needed if the PNGV project is to have a reasonable chance of succeeding. The fact that DOT has decided on a "zero" contribution to PNGV in FY 1996 and that NASA's contributions to the systems analysis work are uncertain beyond FY 1996 suggests a lack of commitment to the program within the administration.

The committee noted that strong coordination among public affairs representatives of all participating agencies could be very beneficial to the PNGV program. The single biggest effort to date appears to have come from DOC, and it is not clear that other government departments have been similarly engaged in helping to build and maintain support for the project. In this context, improved federal program management to support the entire program concept would be beneficial in demonstrating a cohesive, well-defined effort.

The World Wide Web (WWW) site,[1] which has been established on the Internet, is a useful tool for performing public outreach on the program and is a notable PNGV achievement of the past year. Built into this communication device is an allowance for tracking the number of individuals who enter the site, documenting their comments, and identifying their affiliation. Analyzing public input at the WWW site could give the PNGV some understanding of where public support exists, what the criticisms of the partnership are, and how best to respond to public questions and skepticism.

Building liaisons with public interest groups that are interested in the outcome of the program and supportive of its success could also be important in gathering public support. As noted in the Phase 1 report, environmental, community, labor, and other related interest groups could be instrumental in advocating the project, which, in turn, could enhance public and policy-maker support for the partnership.

The committee noted that there are opportunities for the PNGV partnership to enhance links between the project and the larger transportation community. Expanded participation at meetings of automotive and transportation professionals and policy makers could provide an important outlet for public education and support for the partnership. Such forums might include annual meetings of NRC's Transportation Research Board, the Society of Automotive Engineers, the American Association for the Advancement of Science, automotive shows and exhibitions, and other relevant professional and industry meetings. These avenues provide outreach to employees of the U.S. automotive industry and its suppliers and to trade associations and other related groups connected with personal transportation.

The committee noted that the success of the PNGV program depends on members of Congress and their staffs being kept fully apprised by the PNGV of the program's process, goals, and status through regularly scheduled briefings and invitations to attend activities and meetings related to the program. In budget hearings, it could be beneficial for the program's leadership to provide a joint presentation on PNGV, not from one agency, but of the entire program from all federal participants. This would ensure that the Congress has the opportunity to review and fund an entire program and would minimize the problems associated with the traditional piecemeal approach, with each department briefing its appropriations committee on its part of the broad program. The current fragmented approach does not permit an integrated approach to understanding the major benefits resulting from meeting the national goals defined in the PNGV program.

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[1] The PNGV site can be reached directly at http://picard.aero.hq.nasa.gov/index.html.

As indicated by the preceding discussion, opportunities exist for the PNGV to educate the public and policy makers, engage the media, and form liaisons with the public interest community through coordinated policy, outreach, and education efforts. In this context, the committee was encouraged by its observation that, in a number of instances, good working relationships and lines of communication are beginning to be established between the PNGV partners. It appears that the barrier between government and the automotive industry is starting to break down, allowing a fruitful exchange of ideas and resources.

Appendix A

Biographical Sketches

STANDING COMMITTEE TO REVIEW THE RESEARCH PROGRAM OF THE PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

Trevor O. Jones (NAE) is chairman of the board (retired) of Libbey-Owens-Ford Co., a major manufacturer of glass for automotive and construction applications; vice chairman of Echlin Inc., a major supplier of automotive after market parts; and chairman and chief executive officer of International Development Corporation, a private management consulting company. Previously, he was an officer of TRW Inc., serving in various capacities in the company's Automotive Worldwide Sector, including vice president of engineering and group vice president, Transportation Electronics Group. Prior to joining TRW, he was employed by General Motors in many aerospace and automotive executive positions, including director of General Motors Proving Grounds; director of the Delco Electronics Division, Automotive Electronic and Safety Systems; and director of General Motors' Advanced Product Engineering Group. Mr. Jones is a fellow of the American Institute of Electrical and Electronics Engineers and has been cited for "leadership in the application of electronics to the automobile." He is also a fellow of the American Society of Automotive Engineers, a fellow of the British Institution of Electrical Engineers, a registered professional engineer in Wisconsin, and a chartered engineer in the United Kingdom. He holds many patents and has lectured and written on the subjects of automotive safety and electronics. He is a member of the National Academy of Engineering (NAE) and the National Research Council's (NRC's) Commission on Engineering and Technical Systems. Mr. Jones has served on NRC study committees, including the Committee for a Strategic Transportation Research Study on Highway Safety, and chairs the NAE Steering Committee on the Impact of Products Liability Law on Innovation. He holds degrees in electrical engineering from Aston Technical College and mechanical engineering from Liverpool Technical College.

Donald J. Bailey is director for research and technology partnering at the Ohio Aerospace Institute where he is responsible for collaborative teaming activities directed towards advanced technology development, including materials and manufacturing. Dr. Bailey began his career as a senior research metallurgist at General Motors Corporate Research Laboratories with responsibility for research on materials applications for automotive vehicle weight reduction programs. He subsequently joined General Electric Company, where his positions included manager of advanced development engineering and manager of marketing and product technology for the Transformer Business Department. He spent five years as a vice president of Kulhman Corporation, a manufacturer of power distribution transformers and automotive products, before joining the Ohio Aerospace Institute in 1991. Dr. Bailey received his B.S., M.S., and Ph.D. in metallurgical engineering from the University of Washington in Seattle.

Harry E. Cook (NAE) is director of the Manufacturing Research Center at the University of Illinois at Urbana. Previously, he was general manager of scientific affairs, Chrysler Corporation, and director of automotive research and technical systems. He spearheaded the development of the first cooperative research program within the U.S.-based automotive industry, which lead to a precompetitive research joint venture on polymer-based structural composites. He also initiated joint efforts to set industry standards for a new generation of computer-aided design/computer-aided manufacture (CAD/CAM) systems and was instrumental in bringing CAD/CAM technologies and knowledge-based systems to the production line. Prior to joining Chrysler, Dr. Cook held a variety of management positions at the Product Development Group at Ford Motor Company. In 1972, he joined the Department of Metallurgy and Mechanical Engineering at the University of Illinois, where he held a joint full professorship in the two departments. He is a fellow of the American Society of Metals and a fellow of the American Society of Automotive Engineers. He is a member of the NAE and the NRC's National Materials Advisory Board. Dr. Cook served as a member of the NRC Committee on Materials for the 21st Century. He received his B.S. and M.S. degrees in metallurgy from Case Institute of Technology and his Ph.D. in material science from Northwestern University.

R. Gary Diaz is senior vice president of manufacturing and engineering for Case Corporation, with responsibility for providing general management and directing the leadership of global product development and production for an agricultural and construction equipment company. He previously held a number of positions with General Dynamics Land Systems, including division vice president and general manager, Development and Integration Business Unit; vice president, Research Engineering and Logistics; director, Engineering Programs; and engineering manager, Advanced Ground Vehicle Technology. Mr. Diaz participated extensively in the development of the M1A2 Abrams tank; notably, the technology base for system sensors, electronics, communications, and software. He also managed product development and engineering for the advanced amphibious assault vehicle and the heavy assault bridge. Mr. Diaz received his B.S. in mechanical engineering and his M.S. in engineering from the University of Florida.

Kennerly H. Digges is research professor of engineering and director of biomechanics and automotive safety research, George Washington University. Previously, he was a senior executive in the U.S Department of Transportation's National Highway Traffic Safety Administration (NHTSA). At NHTSA, he managed research to advance motor-vehicle crash-safety standards, such as side-impact protection, and led the development of experimental automobiles that protect occupants in severe crashes. He was also head of NHTSA's Rulemaking Office and contributed to the introduction of automatic restraints for new cars. Prior to joining NHTSA, Dr. Digges spent 10 years directing the U.S. Air Force research program in mechanical systems for aircraft. He is a past director of the Transportation Rehabilitation Engineering Center of the National Institute for Disability and Rehabilitation Research. He received his B.S. in mechanical engineering from Virginia Polytechnic Institute and his M.S. and Ph.D. in mechanical engineering from Ohio State University. Dr. Digges is a member of the American Society of Automotive Engineers, serving as a Technical Board member and a seminar instructor in computer accident reconstruction. He is an internationally recognized expert in the field of automotive safety and has published numerous papers on accident characterization and safety performance.

Deborah Gordon is director of energy programs with the Union of Concerned Scientists (UCS). Previously, she was UCS's transportation and energy policy analyst of the Energy Policy Program. She served as research assistant at the U.S. Department of Energy's Lawrence Laboratory and held an L.B.J. Fellowship at the U.S. House of Representatives, working in the area of energy and the environment. She was a chemical and regulatory engineer in the Production Department of Chevron U:S.A., Inc. Ms. Gordon earned her B.S. in chemical engineering at the University of Colorado, Boulder, and her master's of public policy degree at the University of California, Berkeley. Her most recent publication, featured in *Forum for Applied Research and Public Policy*, is titled "Alternative Fuels Versus Gasoline: A Market Niche?" She is the author of the 1991 book, *Steering a New Course: Transportation, Energy and the Environment*, and several other papers and reports. She has delivered expert testimony on energy and environmental issues at the local, state, and national levels.

David F. Hagen is director and president of the Michigan Center for High Technology in Detroit. He spent 35 years with Ford Motor Company, where his most recent position (prior to retirement) was general manager, alpha simultaneous engineer, Ford Technical Affairs. Under his leadership, Ford's alpha activity, which involves the identification, assessment, and implementation of new product and process technologies, evolved into the company's global resource for leading-edge automotive product, process and analytical technologies. Mr. Hagen led the introduction of the first domestic industry feedback electronics, central fuel metering, full electronic engine controls, and numerous 4-cylinder, V6, and V8 engines. Mr. Hagen received his B.S. and M.S. in mechanical engineering from the University of Michigan. He serves on the boards of the Engineering Society of Detroit and the School of Management, University of Michigan-Dearborn, and on the Engineering Advisory Boards of both Western Michigan University and the University of Michigan-Dearborn.

Robert L. Hirsch is president, Energy Technology Collaborative, Inc. of Washington, D.C. Prior to June 1994, he was vice president, Washington Office, Electric Power Research Institute (EPRI). He is a member of the NRC's Board on Energy and Environmental Systems and was a member of the NRC's Energy Engineering Board from 1992–1994. He has also served on several National Research Council committees and was chairman of the Committee to Examine the Research Needs of the Advanced Extraction and Process Technology Program (Board on Chemical Sciences and Technology). Prior to joining EPRI, Dr. Hirsch was vice president and manager, Research and Technical Services Department, ARCO Oil and Gas Company; chief executive officer of ARCO Power Technologies; manager, Exxon Baytown Research and Development Division; and general manager, Exploratory Research, Exxon Research and Engineering Company. Earlier, he served as assistant administrator for Solar, Geothermal, and Advanced Energy Systems and irector, Division of Magnetic Fusion Energy Research, U.S. Energy Research and Development Administration. He holds a Ph.D. in engineering and physics from the University of Illinois.

Craig Marks (NAE) is president, Creative Management Solutions. He is also visiting professor in both the College of Engineering and the School of Business Administration at the University of Michigan and Co-Director of the Michigan Joint Manufacturing Initiative. He is a retired vice president of technology and productivity for Allied Signal Automotive with responsibility for product development; manufacturing; quality; health, safety, and environment; communications; and business planning. Previously, in TRW's Automotive Worldwide Sector, Dr. Marks was vice president for engineering and technology and later served a the vice president of technology at TRW Safety Restraint Systems. Prior to joining TRW, he held various positions at General Motors Corporation, including executive director of the engineering staff; assistant director of advanced product engineering; engineer in charge of power development; electric vehicle program manager; supervisor for long range engine development; and executive director of the environmental activities staff. He is a member of the NAE and a fellow of the Society of Automotive Engineers. Dr. Marks received his BSME, MSME, and Ph.D. in mechanical engineering from the California Institute of Technology.

Seymour L. Meisel (NAE) is retired vice president for research, Mobil Oil Corporation. He was responsible for all corporate research activities directed at exploration, production, refining, catalysis, petroleum products, and petrochemicals. His work also addressed research and development on synthetic fuels from coal and shale, and, as a director of Mobil Solar Energy Corporation, he was involved in a venture to produce photovoltaic systems. Dr. Meisel is a director of Environgen, a fellow of the American Association for the Advancement of Science, and a member of the American Chemical Society and of the American Institute of Chemical Engineers. He is a member of the NAE and served as a member of the NRC's Energy Engineering Board from 1990 thorugh 1994. He is the author or coauthor of many scientific publications, holds a number of patents, and has lectured extensively to university and industrial groups. Dr. Meisel received a Ph.D. in chemistry from the University of Illinois.

Jerome G. Rivard (NAE) is president of Global Technology and Business Development, advising business and universities on global business approaches to automotive electronics. He previously held a number of senior management positions with the Bendix Corporation and Ford Motor Company, including vice president for the Allied Automotive Sector of Bendix Electronics Group; group director of engineering for Bendix Electronic Fuel Injection Division; manager of the Bendix Automotive Advanced Concepts Program; and chief engineer for the Electrical and Electronics Division of Ford. Mr. Rivard built an engineering group with skills in electronics, electromechanical devices, fluid flow control, combustion and power production, and control systems integration. He applied a systems approach to technical discipline management and adopted financial management systems to effectively plan and control engineering projects for maximum return on investment. Mr. Rivard is a member of the NAE and a fellow of the Institute of Electrical and Electronic Engineering and the Society of Automotive Engineers. He received his BSME from the University of Wisconsin.

Vernon P. Roan is director of the Center for Advanced Studies in Engineering and professor of mechanical engineering at the University of Florida, where he has been a faculty member for nearly 30 years. He was previously a senior design engineer with Pratt and Whitney Aircraft. Dr. Roan has over 25 years of research and development experience. He is currently developing improved modeling and simulation systems for a fuel-cell bus program and works as a consultant to Pratt and Whitney on advanced gas turbine propulsion systems. His research at the University of Florida has involved both spark-ignition and diesel engines operating with many alternative fuels and advanced concepts for both types of engine. Together with groups of engineering students he designed and built a 20-passenger diesel-electric bus for the Florida Department of Transportation and a hybrid-electric urban car using an internal combustion engine and lead-acid batteries. He has served as a consultant to the Jet Propulsion Laboratory, monitoring electric and hybrid vehicle programs. Dr. Roan received his B.S. in aeronautical engineering and his M.S. in engineering from the University of Florida and his Ph.D. in engineering from the University of Illinois. He has organized and chaired two national meetings on advanced vehicle technologies and a national seminar on the development of fuel-cell-powered automobiles, and has published numerous technical papers on innovative propulsion systems.

Supramaniam Srinivasan obtained his B.S. degree in chemistry from the University of Ceylon and his Ph.D. degree in physical chemistry from the University of Pennsylvania. His is internationally recognized for his contributions in electrochemistry, electrochemical energy conversion and storage, with emphasis on hydrogen energy technologies and bioelectrochemistry. Dr. Srinivasan established electrochemistry/electrochemical technology laboratories at the State University of New York-Downstate Medical Center, Brookhaven National Laboratory, Los Alamos National Laboratory, Institute for Hydrogen Systems at the University of Toronto, and Texas A&M University. While working in these laboratories, he trained and continues to train visiting scientists and engineers, postdoctoral research associates, and undergraduate and graduate students in fundamental and applied areas. He has promoted mission-oriented research and development projects in electrochemical energy conversion and storage and in bioelectrochemistry, involving collaborations with universities, national laboratories, and industries. He has assisted the U.S. Department of Energy in the technical management of fuel cell, battery and hydrogen energy technology projects. While at Brookhaven National Laboratory, he played a major role in initiating the "Fuel Cells for Transportation Program," sponsored by the U.S. Department of Energy. He has served as the technical secretary to the U.S. delegation for the International Energy Agency Hydrogen Production Research and Development Program. He has organized workshops and/or symposia for the U.S. Department of Energy and the Electrochemical Society. He has more than 200 publications, including a book; chapters in books; reviews; and journal articles. Dr. Srinivasan has been an invited or keynote speaker at several national and international meetings.

Vickie V. Sutton is research associate professor at the Uniformed Services University of Health Sciences, Division of Environmental and Occupational Medicine. Her previous positions include senior policy analyst, and later assistant director, at the White House Office of Science and Technology Policy; special assistant for policy, planning and evaluation at the U.S. Environmental Protection Agency; and executive vice president of Seaguard Corporation, a manufacturer of marine coatings. She has also held positions at George Mason University and the George Washington University. During her tenure at the Office of Science and Technology Policy, Dr. Sutton was responsible for the Federal Coordinating Council for Science, Engineering and Technology, and was extensively involved in coordinating activities among different government agencies as well as the public, private, and intergovernmental sectors. She brings to the committee first-hand experience in the development and implementation of White House initiatives in science, engineering, and technology, including high performance computing and communications, U.S. global climate change research, advanced materials processing, and mathematics and science education. In addition, she has expertise in strategic planning involving he implementation of new technologies and environmental risk and regulatory issues. Dr. Sutton eceived her Ph.D. in environmental science from the University of Texas at Dallas, her M.P.A. from Old Dominion University, and B.S. degrees in zoology and animal science from North Carolina State University.

C. Michael Walton (NAE) holds the Ernest H. Cockrell Centennial Chair in Engineering and is chairman of the Department of Civil Engineering at the University of Texas at Austin. He holds a joint academic appointment in the Lyndon B. Johnson School of Public Affairs. He has been actively involved in research related to transport policy and engineering analysis for approximately 29 years, and he has served on or chaired a number of national study panels. Dr. Walton was elected to the NAE in 1993. He is past-chair of the Executive Committee of the Transportation Research Board of the NRC. He serves on the Board of Directors of the International Road Federation and is chairman of the Technical Activities Committee for the

American Society of Civil Engineers. Dr. Walton received his B.S. in civil engineering from the Virginia Military Institute and his M.S. and Ph.D. in civil engineering from North Carolina State University.

NATIONAL RESEARCH COUNCIL STAFF

Mahadevan (Dev) Mani has recently become the associate executive director of the Commission on Engineering and Technical Systems of the NRC. Previously, Dr. Mani was the director of the Board on Energy and Environmental Systems of the NRC. He has been with the NRC since April 1989. The board conducts a program of activities to provide independent scientific and technical advice to the U.S. government and the private sector on energy and related environmental issues affecting public policy. Dr. Mani came to the NRC from TRW, where he had held various positions since 1975. He was director, federal marketing development, for the Federal Systems Group of TRW's Space and Defense Sector from 1987 to 1989. Previously, he was director, planning and analysis, in TRW's Science and Technology Department. From 1975 to 1983 he was with TRW's Energy Development Group, responsible for the management of projects undertaken for the U.S. Energy Research and Development Administration, U.S. Department of Energy, the Energy Information Administration, the Oak Ridge National Laboratory, and other clients. Dr. Mani received his Ph.D. in energy management and policy from the University of Pennsylvania, his M.S. in materials engineering from Drexel University, and his B.Tech. in metallurgy from the Indian Institute of Technology, Madras.

Jill Wilson is a senior program officer with the Board on Energy and Environmental Systems and was study director for Strategic Assessment of the U.S. Department of Energy Coal Program. She joined the NRC in March 1993 and has worked on studies related to issues in energy, materials engineering, and environmental science. Dr. Wilson was previously a research scientist with a small consulting company in Washington, D.C., investigating aspects of submarine technology. Before coming to the United States in 1988, she was responsible for advanced materials development at British Aerospace Military Aircraft Division, Warton, United Kingdom. She received her B.A. in natural sciences and her Ph.D. in physics, both from the University of Cambridge. She also holds a diploma in liberal arts from the University of Toulouse, France.

Nan Humphrey is a senior staff officer at the Transportation Research Board (TRB), a unit of the NRC. She has been with the Studies and Information Services Division of TRB for nine years and has managed several policy studies, ranging from an evaluation of size regulations for heavy trucks on highway safety, industry productivity, traffic operations, and road wear to a strategic study of highway safety research priorities and programs to a study of data requirements to support transportation policy. Currently, she is managing a study of the effects of highway capacity improvements on air quality and energy consumption, which is jointly funded by the Federal Highway Administration, the Environmental Protection Agency, state departments of transportation (through the National Cooperative Highway Research Program), and TRB. Ms. Humphrey has a master's degree in public and private management from the Yale School of Management.

Wendy Lewallen is a senior project assistant in the NRC's Board on Energy and Environmental Systems. She has been with the NRC since 1993. She received her B.A. in political science, with a minor in education, from the University of Southern California and taught high school social science for two years in Long Beach, California. Ms. Lewallen is currently studying for a master's degree in bilingual/multicultural education at George Mason University.

Appendix B

Committee Meetings and Activities

1. **Committee Meeting, August 28–31, 1995, Dearborn, Michigan**

The following presentations were made to the committee by members of the PNGV:

Scope of the Peer Review—*Mary Good, John McTague*

Review PNGV Response to First Study with USCAR and U.S. Government Executives—*Rob Chapman, Bob Mull*

Overall PNGV Program Status Against Detailed Schedules and Specific Objectives—*Ron York*

PNGV Resource Requirements and Sources—*Peter Rosenfeld, Pandit Patil*

Systems Analysis
- PNGV Decision Process—*Owen Viergutz*
- Vehicle Engineering—*Klaus Winkelmann*
- Systems Analysis—*Mutasim Salman, Harvey Bloomfield*

Review of PNGV Materials Issues, Selection Criteria, and Projected Resources—*John Fillion*

Powertrains
- 4-Stroke Direct Injection Engines—*David Foulkes*
- Fuel Cells—*Chris Borroni-Bird*
- Gas Turbines—*Jerry Skellenger*
- Chemical Batteries and Ultracapacitors—*Harold Haskins*
- Flywheel—*Cyrus Ashtiani, Don Bender*
- Hybrid Electric Vehicle Propulsion Programs—*Brad Bates*

Review of Active Third-Party Support to PNGV Program—*Peter Rosenfeld*

PNGV Infrastructure Issues—*Bob Mull, Larry Johnson*

PNGV Barriers
  Major Barriers to Success in Terms of Technology, Vehicle Cost, Schedules, and Resources—*Ron York*
  Identify Government Agencies with Minimal Support to PNGV Who Have More to Contribute—*Rob Chapman*

The committee also received a demonstration of the PNGV Home Page on the World Wide Web and was provided with written status reports by the PNGV on activities relating to goals 1 and 2.

On August 27, 1995, selected members of the committee and NRC staff received an overview of the PNGV program from representatives of USCAR and the U.S. government.

A review of Ford Concept Vehicle activities was provided to the full committee by Chuck Risch of Ford Motor Company on August 29, 1995.

2. **Committee Meeting, October 30–November 2, 1995, Washington, D.C.**

The committee received the following presentations from representatives of industry and the government, including the national laboratories:

Update on FY 1996 Budget and Impact of Budget Changes on the PNGV Program—*Rob Chapman and Pandit Patil*, PNGV

Materials Technology
  Update on PNGV Technical Roadmap—Materials and Structures, *Andy Sherman*, PNGV
  Steel—*Darryl Martin*, American Iron and Steel Institute (AISI)
  Aluminum—*Mike Wheeler*, Aluminum Association
  Polymer Matrix Composites—*Elio Eusebi*, PNGV
  Composite Vehicle Manufacturing—*Bill Mellian*, Owens Corning
  Why Carbon Fibers?—*Mike Michno*, Amoco

Powertrains—Additional Development Activities
  Reduction of Nitrogen Oxide Emission for Lean Burn Engine Technology—*Stephen Lott*, Sandia National Laboratories, and *Bob Hammerle*, PNGV
  Fuel Additives and Formulations for NO_x Control in Direct Injection Diesel Engines—*Ronald Graves*, Oak Ridge National Laboratory
  Advanced Diesel Engine Technologies—*John Clarke*, Caterpillar, Inc.

Major PNGV Barriers and Achievements—*John Crawford*, Sandia National Laboratory, and *Chris Sloane*, USCAR

Foreign Automotive Technology Development: Electric and Hybrid Vehicles—*Keith Hardy*, TASC Automotive

Moving the Nation with Advanced Transportation—*Tom Gross*, U.S. Department of Energy

Office of Technology Study on Advanced Vehicle Technologies ("Advanced Automotive Technology: Visions of a Super-Efficient Family Car")—*Greg Eyring*, Office of Technology Assessment

Hydrogen-Powered Vehicle Development at BMW—*Joachim Tachtler*, BMW, Germany

Light Duty Engine Technologies—*Ralph McGill*, Oak Ridge National Laboratory

Continuously Variable Transmission (CVT) Systems—*N. Liebrand*, Van Doorne's Transmissie b.v., The Netherlands

Better Automatic Transmissions for Vehicles—*James Dancey*, Automotive Branch, Industry Canada

In addition, a subgroup of the committee and selected members of the PNGV participated in a discussion session on October 31, 1995, on PNGV powertrain development and systems analysis activities.

3. Selected Members of the Committee and NRC Staff Made the Following Site Visits or Attended the Following Symposia:

Visit to Chrysler Liberty Program Center and Vehicle Engineering Center, Madison Heights, Michigan, August 31, 1995

PNGV Symposium, "Energy Storage for the Next Generation Vehicle," September 12–13, 1995, Washington, D.C.

Visit to General Motors Technical Center, Warren, Michigan, October 9, 1995

Visit to Ford Advanced Technology Exhibition, Dearborn, Michigan, October 10, 1995

Automotive Technology Development Contractors' Coordination Meeting, Dearborn, Michigan, October 23–27, 1995

In the course of its deliberations and data-gathering activities, the committee split into several subgroups. The subgroup chairs were Craig Marks (powertrains), David Hagen (materials), and Jerome Rivard (systems analysis).

Appendix C

PNGV Response
to the
Phase 1 Report and Supporting Documentation

PNGV

March 3, 1995

National Research Council
Commission on Engineering and Technical Systems
Board on Energy and Environmental Systems
2101 Constitution Avenue
Washington, DC 20418

Dear Sirs:

The Government/Industry Operational Steering Group (OSG) of the Partnership for a New Generation of Vehicles (PNGV) wishes to thank you for the program review that you performed last year. We especially wish to commend the National Research Council for completing this review so expeditiously and for adopting procedures to protect any proprietary information that may have been needed to provide a more complete understanding of the program. PNGV is an innovative program in many respects and we are pleased that the NRC has entered into the spirit of this national venture to develop more efficient means of public/private sector cooperation.

The NRC report contained a number of findings and recommendations. We have studied these carefully and believe all were helpful perspectives, even when we disagree somewhat on the details. We would like to respond briefly here to some of the major recommendations and offer more detailed dialog during the next peer review.

The NRC noted that the PNGV program needs to have broad national support over a sustained period of time to be able to accomplish its objectives. We agree completely with this observation. We have strengthened our public outreach program and believe that we have made substantial progress in making more people aware of PNGV. Our contacts have provided encouraging signs that support for the program is broad. In addition, recognizing that the new Congress has many questions about PNGV, we have established a joint congressional liaison group to help provide to Congress the information they will need to support PNGV.

We agree with the NRC observation that management of a program with such broad and diverse participation will be a major challenge. We have evolved a tiered structure of an Operational Steering Group and Technical Teams led by competent executives on both the government and industry sides. We believe that this structure is necessary for the effective integration of program elements, between agencies, within agency operating plans and between government and industry. While we recognize that we must be open to innovative suggestions as to how to manage the program more effectively, we do not feel that the suggestion for a single, central program manager for the government is workable. However, we have significantly augmented the resources of the government's PNGV secretariat in order to have more effective and responsive program coordination.

The NRC also recommended that the industry PNGV effort be led by a single technical director in charge of an integrated platform development team at USCAR. We agree that establishing a vehicle perspective is important and while we do not have a complete answer as yet, the industry does plan to add experienced vehicle engineers to each company's PNGV team in the near future to guide the technology development program as it evolves. Also, our view at this time is that each company will pursue separate concept vehicles and production prototypes.

The NRC recommended that we develop a single, central line item in the federal budget for PNGV. Our approach has been to align the technical activities necessary to complete the PNGV program with traditional agency interests, capabilities and operating plans. While admittedly more difficult to manage, we believe that this approach will be less disruptive to the budget preparation and review process and will have better support within agencies and in Congress.

We believe that the PNGV technology strategy is better defined than we were able to effectively communicate to the review panel in the limited time allowed at the time of the first review. Our technical plans have continued to develop: roadmaps have been completed and documented for all breakthrough vehicle technologies and our manufacturing and conventional vehicle programs have both continued to advance in planning and execution. Existing consortia are being utilized where appropriate, and new joint technical teams have been formed, to develop the more detailed programs plans needed to meet the technical roadmaps. These plans will be reviewed in as much detail as possible when the peer review panel next meets with the PNGV team.

The PNGV OSG and technical teams are considering the suggestion of the peer review panel that we divide the technologies being studied into two paths, near-term and far-term. We have not yet resolved how to respond to this suggestion, but will plan to discuss this further internally and with the peer review panel.

Over 100 organizations are already participating in the development of technologies relevant to PNGV. Even so, several actions have already been taken to increase the involvement of suppliers, small entrepreneurs and the academic community in the PNGV program. For example, we are publishing a document which describes "Innovations Needed" and various funding mechanisms available to those who wish to participate in PNGV. We will provide a briefing on this aspect of the PNGV program to the peer review panel.

The NRC peer review suggested that PNGV track and incorporate leading-edge automotive technologies from throughout the world. Each of the members of USCAR and several government agencies routinely evaluate world-wide automotive technology developments.

The OSG and technical teams concur with the peer review about the significance of infrastructure issues on PNGV and vice versa. However, by definition, PNGV is focused on the vehicle, except where infrastructure considerations affect cost. We recognize that the infrastructure issues must involve a broad national dialog to develop appropriate policies and technologies in parallel with PNGV and we expect to be a participant in those discussions.

The PNGV team gratefully acknowledges the willingness of the peer panel members to voluntarily contribute their time and experience to the review of the PGNV program. We expect to derive more value from these reviews and the attendant dialog in the future as we work more closely together. We look forward to the opportunity to build upon last year's hurried introduction and to provide more in-depth briefings on the technical program's plans and progress.

For the PNGV Operational Steering Group,

Mary L Good
Mary L. Good
Under Secretary for Technology
US Department of Commerce

Arv Mueller
Vice President and Group Executive
NAO Vehicle Development and
Technical Operations
General Motors

John P. McTague
Vice President, Technical Affairs
Ford Motor Company

François J. Castaing
Vice President, Vehicle Engineering
Chrysler Corporation

Committee's Analysis of the Letter to the National Research Council from the PNGV Operational Steering Group (3/3/95) Addressing the Recommendations[*] in the Phase 1 Report

(1.) *Recommendation: Program Management*

"...there is a critical need for an initial, integrated plan at the earliest possible time. This unified plan should include, but not be limited to, such key elements as objectives, task descriptions, management responsibilities, milestones, resources, schedule and critical features or metrics that bear on the success of achieving the stated goals of the PNGV program. The committee recommends the creation of these detailed plans to be submitted with the PNGV federal budget for fiscal year 1996."

Response: No response to specific needs were identified. Clarification left for future contact.
"We believe that the PNGV technology strategy is better defined than we were able to effectively communicate to the review panel....roadmaps have been completed and documented for all breakthrough vehicle technologies and our manufacturing and conventional vehicle programs have both continued to advance in planning and execution."

"All three phases of the PNGV program have inadequately defined and staffed program management structures in both government and industry organizations....The government...needs to have a strong and effective central program management office..."

Response: The current structures, as augmented, are adequate.
"We have evolved a tiered structure of an Operational Steering Group and Technical Teams led by competent executives on both the government and industry sides....We do not feel that the suggestion for a single program manager for the government is workable. However, we have significantly augmented the resources of the government's PNGV secretariat in order to have more effective and responsive program coordination."

(2.) *Recommendation: Government Funding and Support*

"The Department of Defense and the National Aeronautics and Space Administration have not provided the PNGV program with a level of support consistent with their technology base."

Response: No specific comment.

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[*] Recommendations are as called out in the Phase 1 report "Review of the Research Program of the PNGV," October, 1994. Responses reflect the committee's initial analysis and reactions to the PNGV statements regarding the committee's recommendations.

"...the committee noted that government and industry technology projects that are related to vehicles integration and to vehicle manufacturing with unconventional materials are minimal through 1997....The committee recommends additional emphasis in the fiscal year 1996 budget on such manufacturing and vehicle related technologies."

Response: No specific comment.

"The committee recommends the establishment of clearly defined mechanisms in fiscal year 1996 for allocating and managing program resources, for selecting and integrating technologies and for assessing total costs and benefits."

Response: No specific comment.

"The committee believes that it is essential that, starting with fiscal year 1996, the government funding of all major and critical elements of the PNGV program be a line-item budget for which oversight responsibility is vested in the government's PNGV program manager. The central control of the PNGV single budget should cut across the government organizations involved in the program."

Response: Not able to get support for a single budget.
"Our approach has been to align the technical activities necessary to complete the PNGV program with traditional agency interests capabilities and operating plans....We believe that this approach will be less disruptive to the budget preparation and review process and will have better support within agencies and in Congress."

(3.) Recommendation: National Commitment

"The committee recommends that the PNGV's public affair groups be adequately supported to perform this important function. This office should commit resources to involving the public in the program, cultivating broad-based support within the policymaking community and taking every opportunity to showcase PNGV achievements for the media."

Response: This is already being done.
"We have strengthened our public outreach program and believe that we have made substantial progress in making more people aware of PNGV....We have established a joint congressional liaison group to help provide to Congress the information they will need to support PNGV."

(4.) Recommendation: Integrated Platform Development Team

"The committee recognizes that each of the three automotive companies may independently want to pursue applications of the technologies developed as a part of Goal 3....Its view is simply that

the overall objectives of Goal 3 must be managed by a single platform team....The co-located USCAR team would have the full authority and responsibility to set the direction for meeting the objectives of Goal 3."

"The committee strongly recommends an early review and reevaluation by USCAR of this proposed need."

Response: Under consideration but with separate vehicles for each company.
"We agree that establishing a vehicle perspective is important and while we do not have a complete answer yet, the industry does plan to add experienced vehicle engineers to each company's PNGV team in the near future to guide the technology development program as it evolves. Also our view at this time is that each company will pursue separate concept vehicles and production prototypes."

(5.) Recommendation: Technology Strategy

"Since no metrics are contained in either Goal 1 or Goal 2, it is currently not possible to measure progress toward achieving these goals....To effectively manage the current PNGV program, appropriate metrics are required."

Response: No mention of metrics.
"Our manufacturing and conventional vehicle programs have both continued to advance in planning and execution."

"It will be important for the managers of this program to develop a more formal mechanism to justify the technology selection choices being made. Establishing such a mechanism should be seriously considered before funds are requested for the fiscal year 1996 budget."

Response: No specific mechanisms mentioned/
"We believe that the PNGV technology strategy is better defined than we were able to effectively communicate to the review panel....roadmaps have been completed and documented for all breakthrough technologies..."

"...the manufacturing development activities conducted for Goal 1 may very well pace the progress of the PNGV. The three areas of focus for this goal need to be expanded and much more detail developed in terms of potential contributing manufacturing technologies. This activity deserves a very high priority at this time."

Response: No acknowledgment of the issue.

"The committee recommends that an analysis be made now to divide all technologies related to Goal 3 into two categories: current PNGV and post-PNGV technologies."

"The committee recommends that technologies that do not meet PNGV program objectives by 1997 but that have high long-term potential be funded and continued in development for post-PNGV applications."

Response: Under consideration.
"The PNGV OSG and technical teams are considering the suggestion of the peer review panel that we divide the technologies being studied into two paths, near-term and far-term."

(6.) Recommendation: Supplier and University Involvement

"The committee was informed that several workshops are being planned in the upcoming months to explore with university and industry representatives the scientific, engineering, and technological issues posed by the PNGV program....The committee recommends that the PNGV workshop structure be quickly expanded to more effectively involve these constituents and to provide them with a link to the PNGV program."

Response: No specific comment.

"In the past many barriers have prevented effective use of the technology existing in the automotive supply base....The PNGV may have to develop some innovative working relationships in order to tap this technology source effectively."

Response: Many are already involved.
"Over 100 organizations are already participating in the development of technologies relevant to PNGV."

"A management approach that should be considered is the formation of specialized consortia made up of the automotive industry, its suppliers, and the government to develop the most critical and promising technologies needed for success on Goal 3."

Response: Publishing list of needs.
"We are publishing a document which describes 'Innovations Needed' and various funding mechanisms available to those who wish to participate in PNGV."

(7.) Recommendation: Foreign Technology

"It would be appropriate for the PNGV program to more fully evaluate applicable non-U.S. technology developments and to integrate selected developments into the program."

Response: Already doing it.
"Each of the members of USCAR and several government agencies routinely evaluate worldwide automotive technology developments."

(8.) *Recommendation: Infrastructure and Capital Needs*

"The long-term impact and enormity of potential discontinuities in the road-vehicle-fuel infrastructure, vehicle service, and vehicle manufacturing sectors are such that these considerations must be addressed as integral parts of the PNGV program systems analysis at the earliest possible time."

Response: Only partially within the scope of the program.
Regarded as "...integral parts of the PNGV program systems analysis..." However, "...PNGV is focused on the vehicle, except where infrastructure considerations affect cost....Infrastructure issues must involve a broad national dialog ...and we expect to be a participant in those discussions."

(9.) *Recommendation: Peer Reviews of the PNGV*

"The...committee...is available to meet with the PNGV to discuss the recommendations provided herein. The committee proposes conducting further reviews in early 1995....more-detailed review of the program's technological decisions, research results, and organizational structures should be actively pursued. The committee proposes conducting such expanded reviews in early 1995."

Response: Need acknowledged.
"We would like to respond briefly here to some of the major recommendations and offer more detailed dialog during the next peer review."

(10.) *Recommendation: Timely Correction of Program Deficiencies*

"In the interest of maintaining the viability of the PNGV program, the committee strongly recommends that the government and industry partners address program deficiencies at the earliest possible time."

Response: As indicated above. (Peer review report issued October 1994. Letter dated March 3, 1995.)

Appendix D

United States Council on Automotive Research Consortia

The U.S. automobile industry, through USCAR, has implemented collaborative projects that directly or indirectly support Partnership for a New Generation of Vehicles objectives. These USCAR consortia are:

- Low Emissions Technologies R&D Partnership (LEP)
- Automotive Materials Partnership (USAMP)
- Supercomputer Automotive Applications Partnership (SCAAP)
- CAD/CAM[1] Partnership
- Natural Gas Vehicle Technology Partnership (NGV)
- Advanced Battery Consortium (USABC)
- Vehicle Recycling Partnership (VRP)
- Auto/Oil Quality Improvement Research Program
- Environmental Research Consortium (ERC)
- Low Emission Paint Consortium (LEPC)
- Electrical Wiring Component Applications Partnership (EWCAP)

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[1] CAD = computer-aided design
CAM = computer-aided manufacture

Partnership for a New Generation of Vehicles

USCAR CONSORTIA ALIGNMENT WITH PNGV GOALS

Consortia	Consortia Goal	Aligned PNGV Goal	1995 Accomplishments
United States Automotive Materials Partnership (USAMP)	To develop lighweight materials for improved automotive fuel economy. • Polymer Composites (ACC) • Light metals (Al, Mg, metal matrix composites) • Engineered Plastics • Cast Iron • Steel • Ceramics	Lightweight Vehicle	• Negotiated cooperative agreement with DOE for $30 M over 5 years • Conducted PNGV Goal III composites and aluminum supplier workshops • Successful cart crash of Escort composite front end • Completed design phase of Focal Project II Composite Pickup Box (28% weight save and cost equal to steel plus liner) • Completed second edition of Materials Characterization Test Procedures manual and obtained SAE approval as industry standard
Low Emissions Technologies R&D Partnership (LEP) Engine Support Systems Technologies (ESST)	Identify enabling technologies for improvements in emissions in the following areas: • Fuel preparation & control, Combustion & HC Control • Cold bag aftertreatment, OBDII, 100K Compliance • Evaporative emissions control	Efficient/ Low Emissions Powertrain	• Demonstrated feasibility of spray formed tooling using low melting point alloys • Produced test sections of dual wall manifolds to support cold start emissions reduction • Developed hydrous metal oxide materials for NO_x reduction catalysts • Developed three new catalyst systems based on Sol-gel/Aerogel technology • Established world-class lean burn and diesel catalyst evaluation facilities at the Oak Ridge National Lab
Environmental Research Consortium (ERC)	• To develop common emissions testing instrumentation and methods • Improve the understanding of vehicle and mfg. emissions on the environment • Reduce environmental impact of mfg. emissions • Reduce worker exposure to mfg. emissions	Efficient/Low Emissions Powertrain and Manufacturing Processes	Emissions Research: • Canister purge & Modal mini-diluter developed • Prototype instruments developed • Reference ULEV vehicle built Emissions Assessment: • Georgia Tech/EPA on-road vehicle emissions measured/analyzed • Michigan Remote Sensing project assessed remote sensing accuracy and high emission vehicle repair effectiveness Atmospheric Modeling: • Modeling runs identified differences in ground level ozone and agreement on the impact of HC and NO_x controls

Partnership for a New Generation of Vehicles

USCAR CONSORTIA ALIGNMENT WITH PNGV GOALS

Consortia	Consortia Goal	Aligned PNGV Goal	1995 Accomplishments
United States Advanced Battery Consortium (USABC)	To pursue R&D of advanced energy systems capable of providing future generations of Electric Vehicles and Hybrids with significantly increased range and performance	Efficient Energy Storage and Conversion	• Initiated downselect process to manage mid-term and long-term technologies within financial constraints • Received initial lithium polymer demonstration cells • Powering Chrysler/Ford/GM vehicles with mid-term tech. batteries • Phase II program proposal submitted to DOE to cover: - Commercialization of mid-term battery technologies - R&D of long-term battery technologies • PNGV energy storage system proposal process initiated
Low Emissions Paint Consortium (LEPC)	• Test and evaluate materials, equipment, and facilities with low emission potential • Develop and demonstrate new low emission processes • Establish common industry database • Focus initially on powder painting technologies	Environmental Responsibility	• Began construction of $20M Powder Clearcoat System at Ford Wixom • Participated in powder primer launches at GM & Chrysler plants and established powder primer launch manual • Issued joint mat'l specifications for Powder CC & Primer • Filed for 2 U.S. Patents based on testing at GM
Supercomputer Automotive Applications Partnership (SCAAP)	Develop portable software easily run on a wide variety of high performance computers by automotive design engineers to: • Shorten product lead time to meet environmental standards • Increase the use of advanced materials, such as carbon fiber, in automotive body parts	Efficient Vehicle Design Processes	• Released advanced CFD code for Aero and Engine Intake Flow Dynamics • Developed library of non-linear analytical material models for improved crash simulations • Incorporated auto-grid generation to improve CAE time • Initiated industry benchmarking effort to assess high performance computers
Vehicle Recycling Partnership (VRP)	• Reduce the environmental impact of vehicle disposal • Increase the efficiency of component disassembly to enhance vehicle recyclability • Develop mat'l selection and design guidelines • Promote socially responsible/economical solution to vehicle disposal	Achieve 80% Vehicle Recyclability Objective	• Established Vehicle Recycling Development Center in Highland Park and initiated technical programs in: - Seat recycling - Fluid reclamation - Disassembly protocols - Airbag dismantling/processing - Time/motion dismantling studies • Developed design guidelines for recycling

Partnership for a New Generation of Vehicles

USCAR CONSORTIA ALIGNMENT WITH PNGV GOALS

Consortia	Consortia Goal	Aligned PNGV Goal	1995 Accomplishments
CAD/CAM Partnership	To promote and apply the concepts of feature-based modeling technology to accelerate new product introduction and reduce complexity in automotive design and manufacturing processes	Efficient Vehicle Design Processes	• Initiated discussions with Fraunhofer-Berlin on CAD Feature based modeling
Natural Gas Vehicle Technology Partnership (NGVT)	Sponsor the development of pre-competitive fuel storage technologies and gas composition standards to support production of more commercially viable natural gas vehicles by 1998	Develop Alt. Fuel Technologies to support reduced emissions	• Established cooperative relationship with Gas Research Institute • USCAR/Gas Industry developed environmental test and specification for storage tanks • Storage tank cost reduction assessment complete resulting in a potential 23% cost savings • Fuel composition emission, performance, and component freeze-up testing 50% complete
Auto/Oil Air Quality Improvement Research Program	To develop data for use by legislators, regulators, and the public on the potential improvements in vehicle emissions and air quality, primarily ozone, from reformulated gasoline, alternative fuels, and developments in automotive technology	Reduced emissions	• Demonstrated that changes in gasoline composition will reduce vehicle emissions by 15-25% • Completed all emissions testing for the program • Published 13 tech. papers, including results of reformulated gasoline, ethanol, methanol, and CNG tests • Established database used by government to support environmental decision making
Electrical Wiring Component Application Partnership (EWCAP)	To develop common designs for electrical connectors to reduce cost and complexity, while improving reliability, quality, and serviceability	Affordability	• Developed common cigarette lighter specification • Design 95% complete and programmed for '97/98 G38 Ford/Chrysler/GM vehicles • Developed electrical connection guidelines and published • Developed common footprint for fuel injector connector • Developed common footprint for ABS module connector • Initiated development of common 1.0mm pin and trailer tow connectors
Strategic Standardizaiton Board (SSB)	Reduction in non-value added product development and manufacturing costs through the standardization of parts, components, and engineering processes across the U.S. Auto Industry	Affordability	• Established forum for industry standardization discussions • Developed process for guiding industry agreements through established standards publishing bodies • Stimulated ANSI to re-evaluate its strategic direction • Commonized 20 nylon standards (down from 120) • Commonized on standard design and process FMEAs • Prioritized parts for joint engineering standardization

USCAR CONSORTIA ALIGNMENT WITH PNGV GOALS

Consortia	Consortia Goal	Aligned PNGV Goal	1995 Accomplishments
Occupant Safety Research Partnership (OSRP)	To conduct R&D on crash-test dummies and related areas such as modeling, instrumentation, data management and reduction, and subsystem safety test development	Safety & Occupant Protection	• Completed prototype fabrication of next generation side impact dummy (SID-IIs). Testing and evaluation in G42 progress • Continued evaluation of NHTSA advanced dummy thorax • Initiated working group with NHTSA on lower extremity instrumentation • Initiated working group on common crash test instrumentation specifications

Appendix E

PNGV Position Regarding Electric Vehicles

Allan D. Murray
Technical Planning Manager
New Generation of Vehicles Program Office
Ford Motor Company

The American Rd, Rm 334
P.O. Box 1899
Dearborn, Michigan 48121-1899
Telephone: 313-[illegible]
Rapifax: 313-[illegible]

December 6, 1995

Mr. Trevor O. Jones
National Research Council
2101 Constitution Avenue
Washington, DC 20418

Subject: Electric Vehicle Position

Reference: Your November 21, 1995, Memo (Attached)

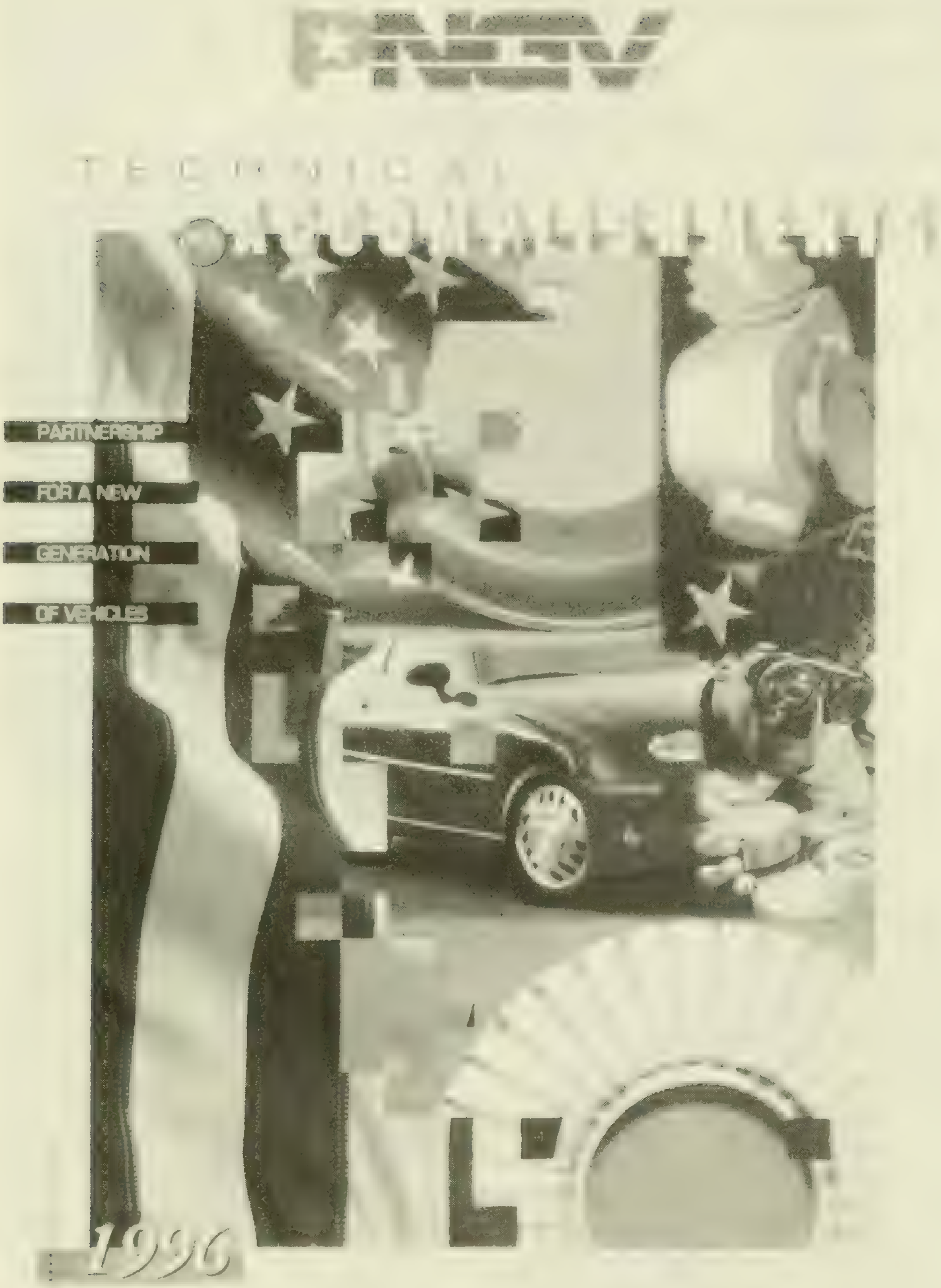
You requested PNGV to provide a position on straight electric vehicles (vs hybrid electrics). As you know, USCAR sponsors active development of electric vehicle energy storage devices, and each OEM has aggressive electric vehicle development programs. There are many common needs between straight electric vehicles and hybrid electric vehicles. Both require maximum weight reduction, high efficiency electric motors, inverters, low energy accessories, low rolling resistance tires, etc.

Primarily as a result of limitations in existing and projected energy storage devices, straight electrics in the PNGV timeframe are unlikely to meet PNGV's objectives of affordability and functional equivalence. Functional limitations include range, speed of "re-fueling", and package space and there are infrastructure concerns. Affordability issues include the initial cost and replacement cost of high-energy storage devices.. The cost of electric drivetrains and associated power electronics must also come down, as they must for hybrid electrics.

Electric vehicles have a relatively low probability of meeting the PNGV "Goal 3" requirements within the next decade. In the long-term we anticipate that possible significant improvements in the cost and efficiency of storage devices, electric drives and high power electronics could be achieved. Thus, the possibility of significant "breakthrough" improvements which would make straight electric vehicles viable, cannot be totally ruled out.

cc: Rob Chapman
denny Freitag
Bob Mull
Peter Rosenfeld
Ron York

Attachment



PNGV

TECHNICAL ACCOMPLISHMENTS

PARTNERSHIP
FOR A NEW
GENERATION
OF VEHICLES

1996

TECHNICAL ACCOMPLISHMENTS

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For Media or General Inquiries, please contact:

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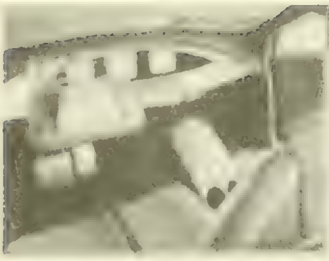

VEHICLE ENGINEERING TECHNOLOGY

Ford Synergy 2010 Concept Car

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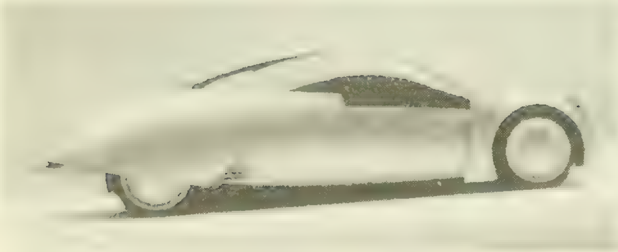

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Background

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Dodge Intrepid ESX

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U [illegible]

[illegible]

[illegible]

[illegible]

GM EV1 Electric Vehicle

[illegible]

Background information

[illegible]

[illegible]

Significant Accomplishments

[illegible]

Smaller, Lightweight Airbag

[illegible]

[illegible]

T[illegible]

Significant Accomplishments

[illegible]

B

[illegible]

[illegible]

Chrysler's Hybrid Propulsion Systems Development Program

Ford Motor Company Hybrid Propulsion Systems Development Program

[illegible]

Potential Payoff/Benefits

[illegible]

Significant Accomplishments

[illegible]

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Background Information

[illegible]

VEHICLE ENGINEERING TECHNOLOGY

General Motors Hybrid Propulsion Systems Development Program

[illegible] *pipe emissions, and meeting market requirements for* [illegible]

Project Facts Benefits

[illegible]

Significant Accomplishments

[illegible]

Research Partners

[illegible]

Background information

[illegible]

PNGV

INTERNAL COMBUSTION ENGINE TECHNOLOGY

Design of Small Compression-Ignition, Direct-Injection (CIDI) Engines

B

[illegible]

[illegible]

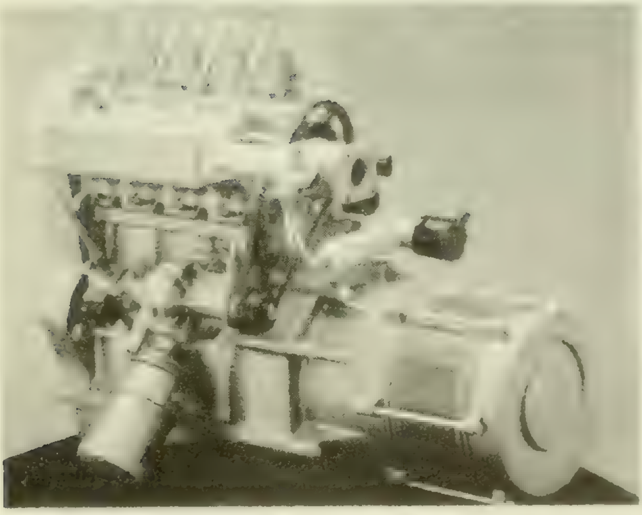
[illegible] are heavier [illegible] tweight [illegible]

[illegible]

C[illegible]

[illegible] Accomplishments

[illegible]



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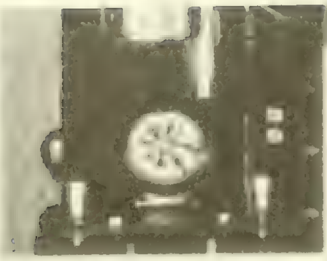
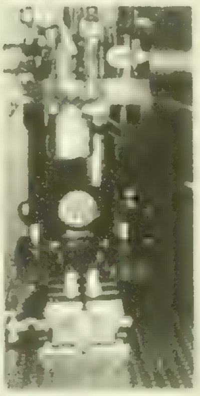
PNGV



"In Cylinder" Engine Analysis

[illegible]

K [illegible]



[illegible]

Reduction of Nitrogen Oxide Emission for Lean Burn Engine Technology

Cylinder Design for Reduced Emission Origins

[illegible]

Background information

[illegible]

Project Payoffs Benefits

W[illegible]

[illegible] Accomplishments

[illegible]

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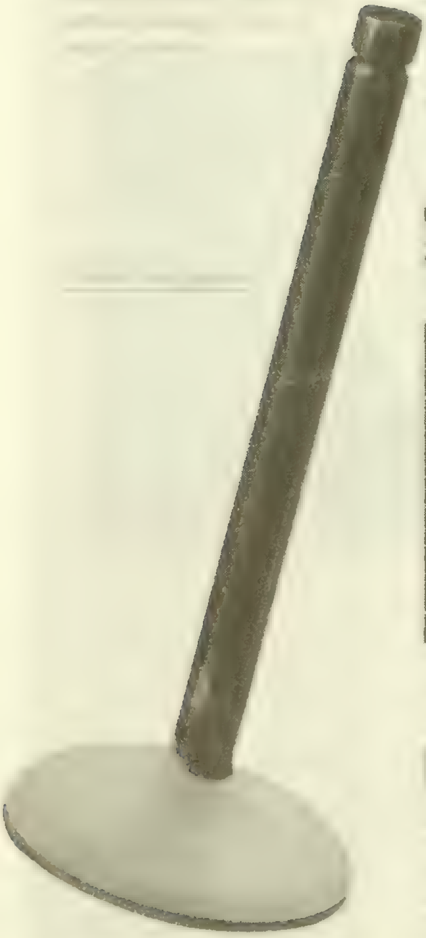

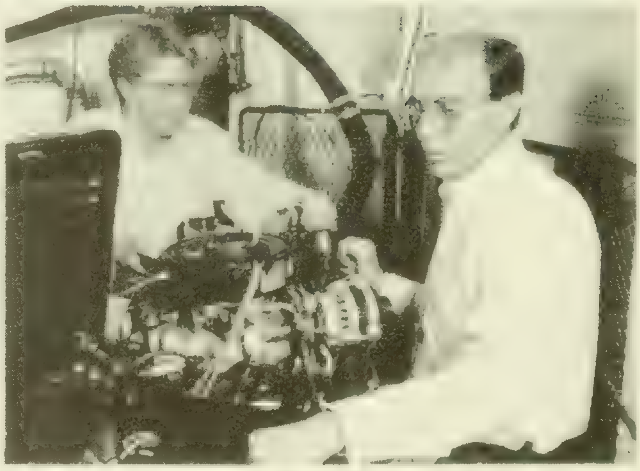

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[illegible]

PNGV

Vacuum Insulated Catalytic Converter

[illegible]

B [illegible]

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Background information

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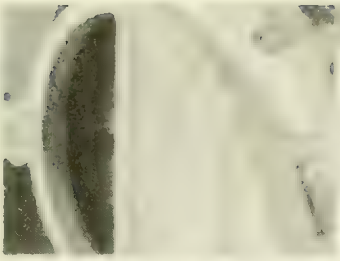
INTERNAL COMBUSTION ENGINE TECHNOLOGY

Plasma Treatment of Automotive Exhaust to Reduce Emissions



Testbed Turbine Engines

[illegible]

[illegible]

Ceramic Materials and Processing

[illegible] materials. Gelcasting is a new way to [illegible]

Background information

[illegible]

Project Results/Benefits

G [illegible]

Significant Accomplishments

[illegible]

Research Partners

[illegible]

Turbine Heat Recovery System

[illegible]

[illegible]

T[illegible]

Significant Accomplishment

[illegible]

Background Information

[illegible]

[illegible]

[illegible]

[illegible]

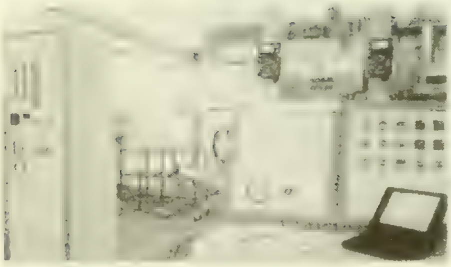
Multi-Fuel Processors for Fuel Cells Used in Vehicles

[illegible]

[illegible]

Project Payoff Benefits

[illegible]



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Significant Accomplishments

- [illegible]
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Research Partners

[illegible]

[illegible]

30 kW Liquid Methanol-Fueled Proton Exchange Membrane (PEM) Fuel Cell Power System

[illegible] (ULEV) standards

Project Payoffs Benefits

T[illegible]

Significant Accomplishments

- [illegible]
- [illegible]
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- [illegible]

[illegible]

[illegible]

B

Background Information

[illegible]

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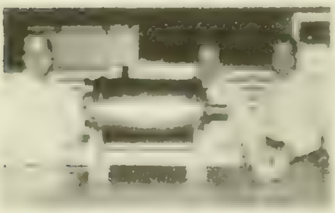
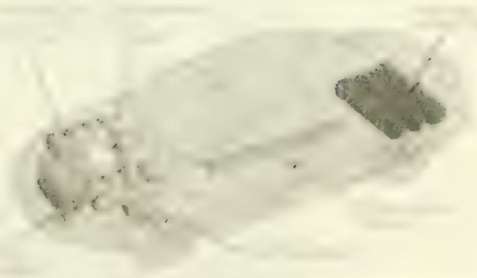


[illegible]

Materials Development in Support of Direct-Hydrogen-Fueled Proton Exchange Membrane Fuel Cells

[illegible]

P [illegible]



On-board Hydrogen Storage Using Lightweight Pressure Vessels

[illegible] *Department of Energy-Ford Motor Company program*

8

Integrated Information

[illegible]

Project Payoffs/Benefits

C [illegible]

Significant Accomplishments

[illegible]

- [illegible]
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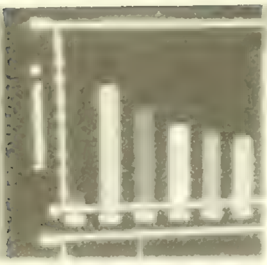
PNGV



Quick-Start Catalytic Methanol Partial Oxidation Reformer for Automotive Fuel Cell

[illegible]

Dramatic Lowering of Precious Metal Catalyst Loading in High Performance Proton Exchange Membrane (PEM) Fuel Cells

[illegible]

Project Payoffs/Benefits

B [illegible]

Significant Accomplishments

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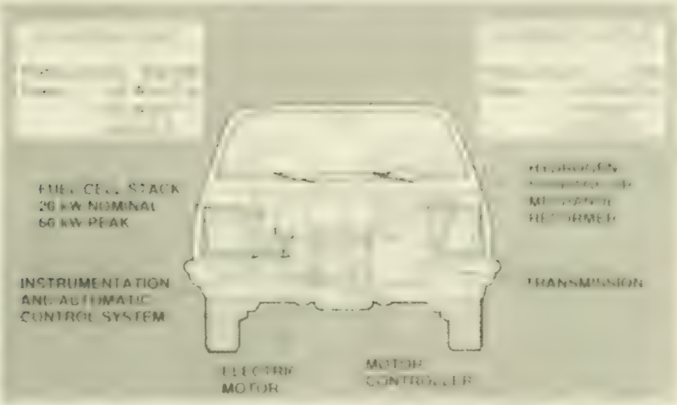

Background Information

[illegible]

[illegible]

PNGV

35-249 96 – 12

Increasing Fuel Cell Tolerance to Fuel Impurities

[illegible]

R [illegible]

[illegible]

[illegible]

Development of Effective Fuel Cell Computer Codes and Diagnostics

[illegible]

[illegible]

[illegible]

Significant Accomplishments

[illegible]

B

[illegible]

Advanced Large Scale PEM Fuel Cell System Test Stand

[illegible]

A [illegible]

Significant Accomplishments

[illegible]

FUEL CELLS

Direct Hydrogen-Fueled Proton Exchange Membrane (PEM) Fuel Cell System for Transportation Applications

[illegible]

Project Payoff/Benefits

[illegible]

Significant Accomplishments

- [illegible]
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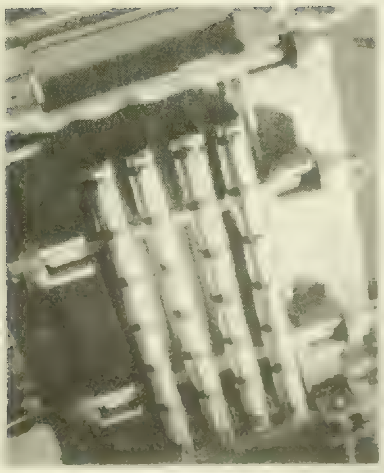

[illegible]

Background information

[illegible]

[illegible]

ENERGY STORAGE

Electrode Materials For Lithium-Ion Rechargeable Batteries

Ultracapacitor Development

[illegible]

Project Goals/Benefits

U[illegible]

- [illegible]
- [illegible]
- [illegible]
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- [illegible]

Significant Accomplishments

- [illegible]
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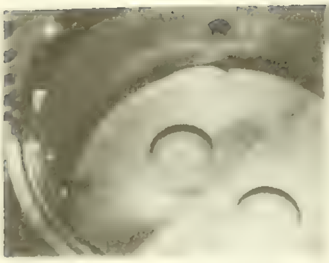
B

Background Information

[illegible]

[illegible]



B

Background Information

[illegible]

High Energy Density Capacitors Using Multilayer Technology for High Performance

[illegible]

Project Description

M[illegible]

Significant Accomplishments

[illegible]

[illegible]

High-Power Density, Double-Layer Ultracapacitors Based on Carbon Aerogels

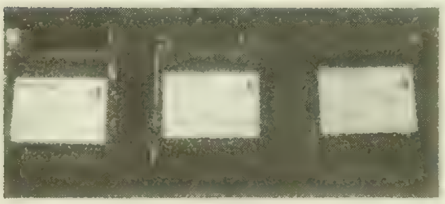
[illegible]

Project Payoffs Benefits

A [illegible]

B

[illegible]



Significant Accomplishments

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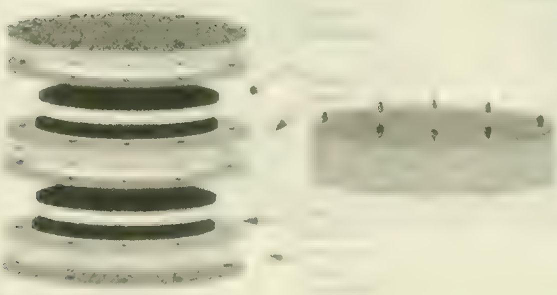

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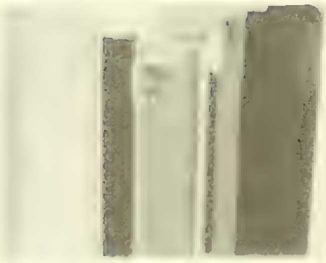
NGV



Flywheel Energy Storage

[illegible]

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[illegible]

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[illegible]

[illegible]

Composite Flywheel Safety and Containment Research and Development

[illegible]

[illegible]

J [illegible]

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Background Information

[illegible]

Significant Accomplishments

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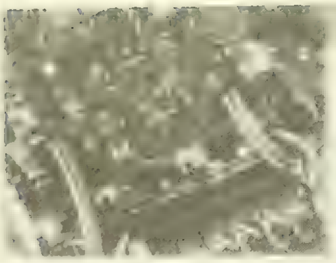


Resonant Snubber Inverter for Hybrid Vehicles

[illegible]

W [illegible]

Significant Accomplishments

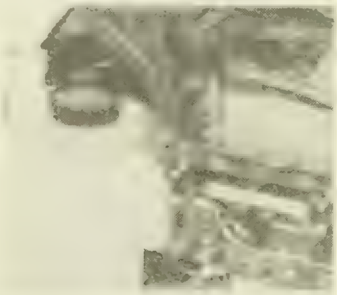
[illegible]

Engine and Battery Fluid Condition Sensor Development

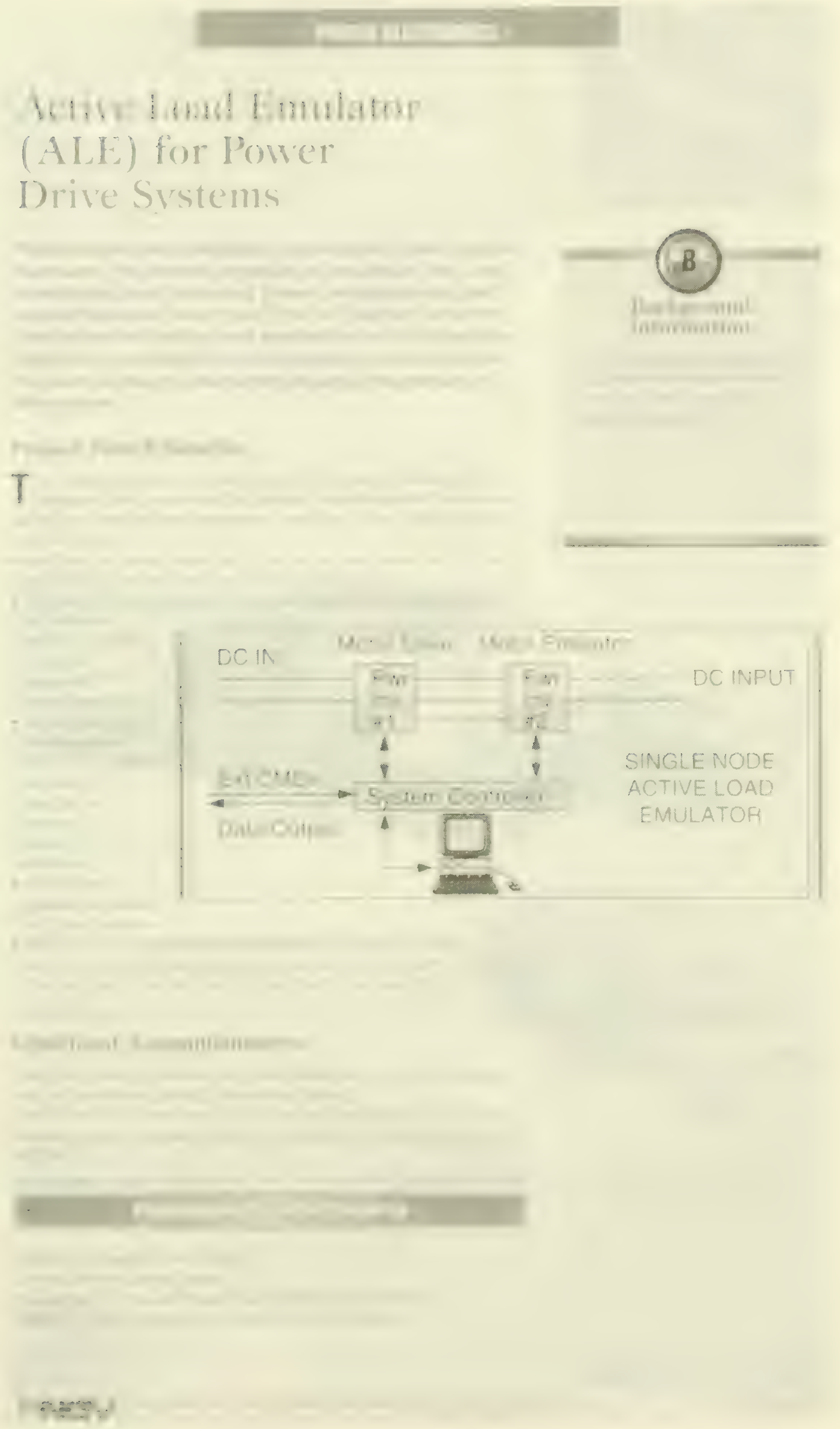
[illegible]

Project Payoffs Benefits

[illegible]



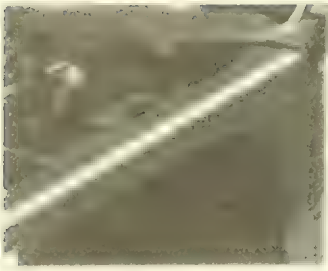
Power Electronic Building Blocks (PEBB) Development Program



Active Load Emulator (ALE) for Power Drive Systems

Background Information

DC IN
Motor Drive
Motor Emulator
DC INPUT
Ext CMDs
System Controller
Data Output
SINGLE NODE
ACTIVE LOAD
EMULATOR



UltraLight Steel Auto Body

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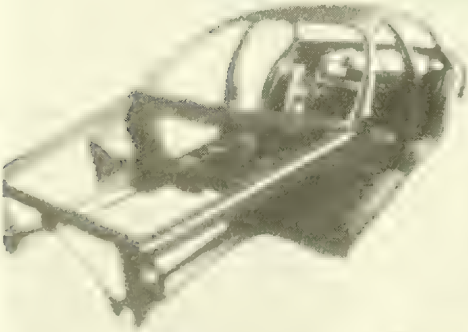
T [illegible]



[illegible]

MATERIALS AND STRUCTURES

Composite Crash Energy Management

[illegible]

[illegible]

[illegible]

[illegible]

Significant Accomplishments

- [illegible]
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- [illegible]

[illegible]

B

Background information

[illegible]

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Durability of Lightweight Composite Structures

K

Adhesive Bonding Technologies for Automotive Structural Components

[illegible]

[illegible]

[illegible]

Significant Accomplishments

[illegible]

[illegible]

Background Information

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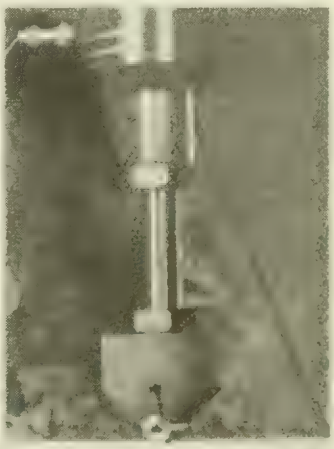

Design and Product Optimization for Casting Lightweight Metals

Rapid Tooling For Functional Prototyping Of Metal Mold Processes

[illegible]

8

[illegible]

MATERIALS AND STRUCTURES

Automotive Materials Recycling

8

Background information

Lightweight Stainless Steel Vehicle Structure Concept

[illegible]

Background information

[illegible]

T [illegible]

Significant Accomplishments

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]

MATERIALS AND STRUCTURES

Standardization of Test Procedures for Automotive Structural Composite Materials

[illegible]

Significant Accomplishments

[illegible]

Automotive Composite Structures: Development of High-Volume Manufacturing Technology

[illegible]

[illegible]

T[illegible]

Significant Accomplishments

[illegible]

- [illegible]
- [illegible]
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[illegible]

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[illegible]

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Background information

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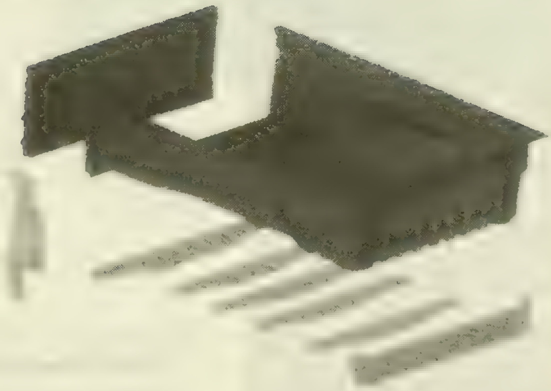

Diamond and Diamond-Like Carbon Coatings

Nickel-Aluminide Forging Dies

[illegible]

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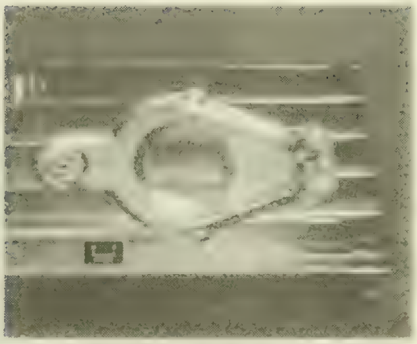

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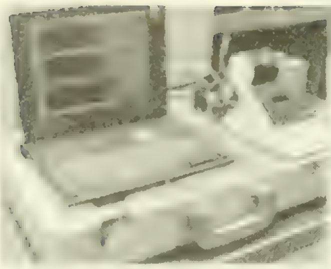

B

[illegible]

Intelligent Welding Of Thin Metal Sections

[illegible]

[illegible]

A

- [illegible]
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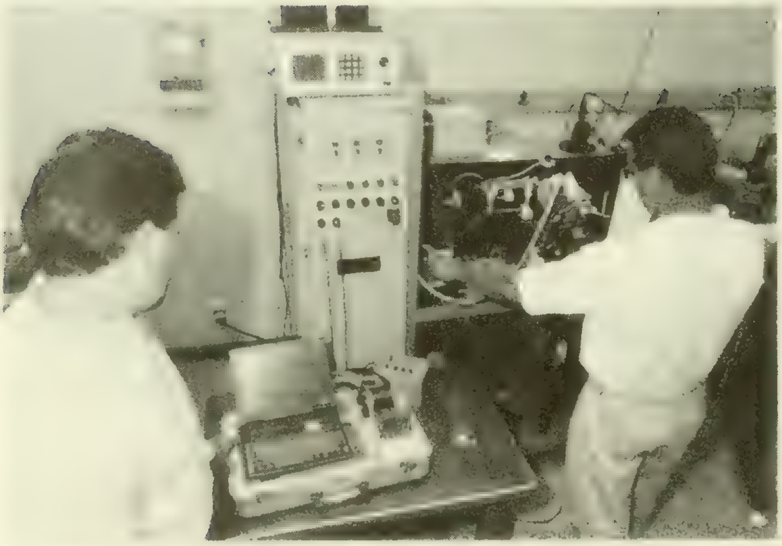
Significant Accomplishments

- [illegible]
- [illegible]
- [illegible]



[illegible]

Research Partners

[illegible]

Aluminum Welding

[illegible]

[illegible]

S[illegible]

Significant Accomplishments

- [illegible]
- [illegible]

B

Background Information

[illegible]

[illegible]

[illegible]

[illegible]

B

[illegible]

Process Control for Laser Beam Welding

[illegible]

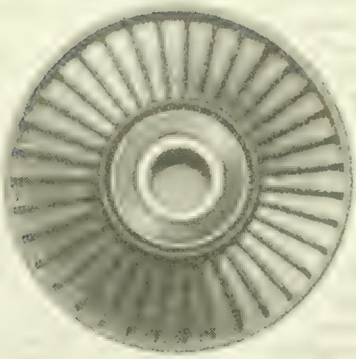
[illegible]

Superplastic Forming of Stainless Steel Automotive Components

8

Spray Formed Tooling for Automotive Components

[illegible]



Plasma-Source Ion Implantation

[illegible]

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[illegible]

Intelligent Induction Heating and Hardening

[illegible]

Background Information

[illegible]

[illegible]

[illegible]

- [illegible]
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[illegible]

Significant Accomplishments

- [illegible]
- [illegible]
- [illegible]
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- [illegible]

[illegible]

[illegible]

Depositing and Non-Destructive Evaluation (NDE) of Thermally Sprayed Coatings

[illegible] *other methods*

Project Payoffs/Benefits

T[illegible]

Significant Accomplishments

- [illegible]
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[illegible]

[illegible]

PNGV [illegible]

Strategic Machine Tool Technologies: Spindles

High-Performance, Environmentally Compatible Painting Technology

B

[illegible]

[illegible]

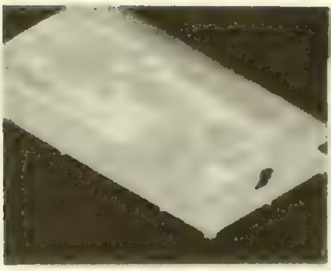
[illegible]

T [illegible]

Significant Accomplishments

[illegible]

[illegible]



Technologies Enabling Agile Manufacturing (TEAM)

[illegible]

Background Information

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Project Payoffs/Benefits

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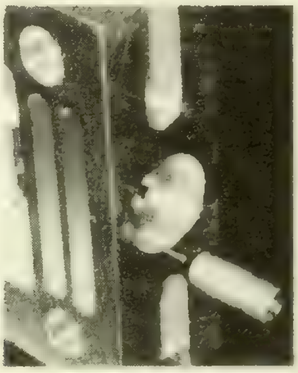

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Research Partners

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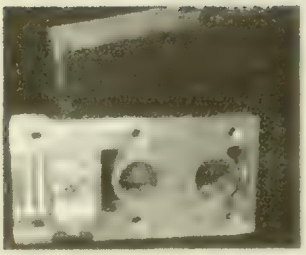

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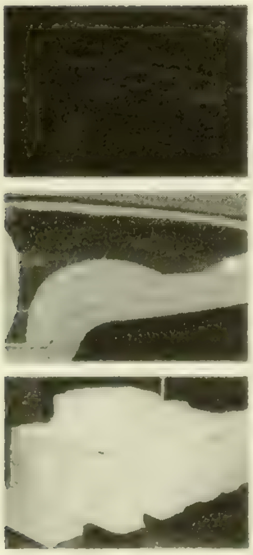

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Background information

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Research Partners

[illegible]

PNGV Simulation Tool

W

PNGV

SYSTEM ANALYSIS

Advanced Modeling Tools for Tire Engineering Process Analysis

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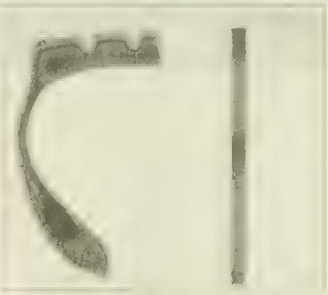
THERMAL/MECHANICAL PROCESSING TYPICAL OUTPUT



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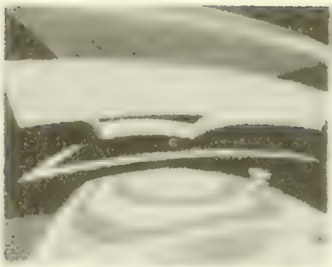
PNGV



Exponential Improvement of Graphics, Engineering and Networking using Virtual Reality (EIGEN/VR)

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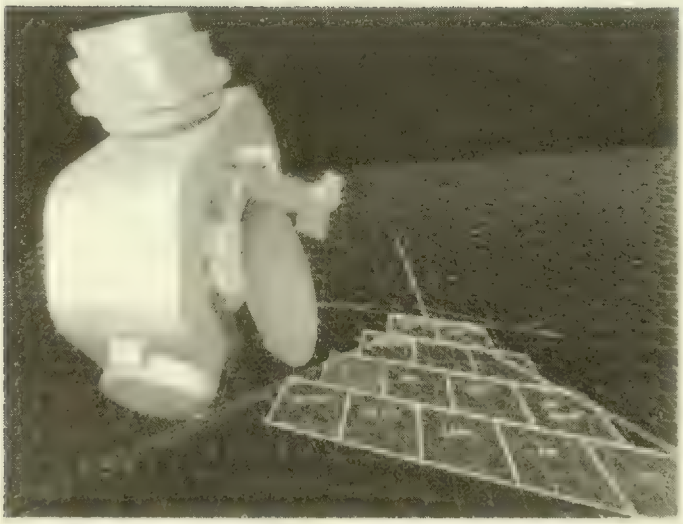

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SYSTEM ANALYSIS

Baseline Systems Analysis Vehicle Simulation Benchmarking

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Background Information

[illegible]

Project Payoffs Benefits

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Significant Accomplishments

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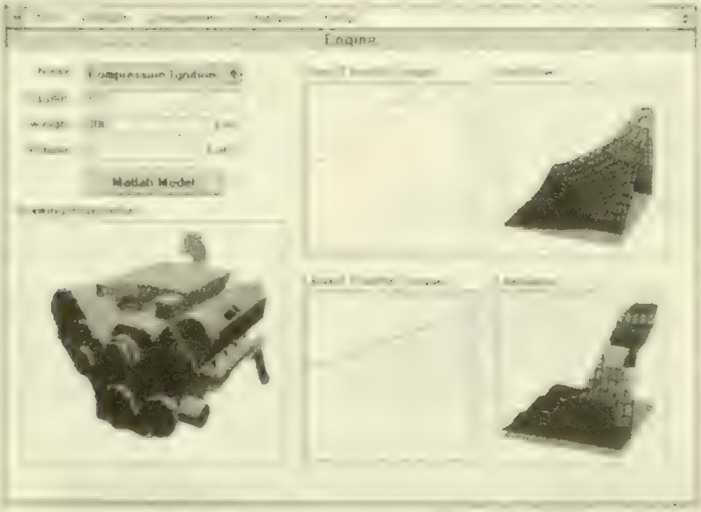

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Application of High-Performance Computing to Automotive Design and Manufacturing

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TECHNICAL ACCOMPLISHMENTS

PNGV℠
PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

PROGRAM PLAN

NOVEMBER 29, 1995

This document is a revision of the program plan originally released by Vice President Gore at the Automotive Technology symposium on July 27, 1994.

Document revised on November 29, 1995

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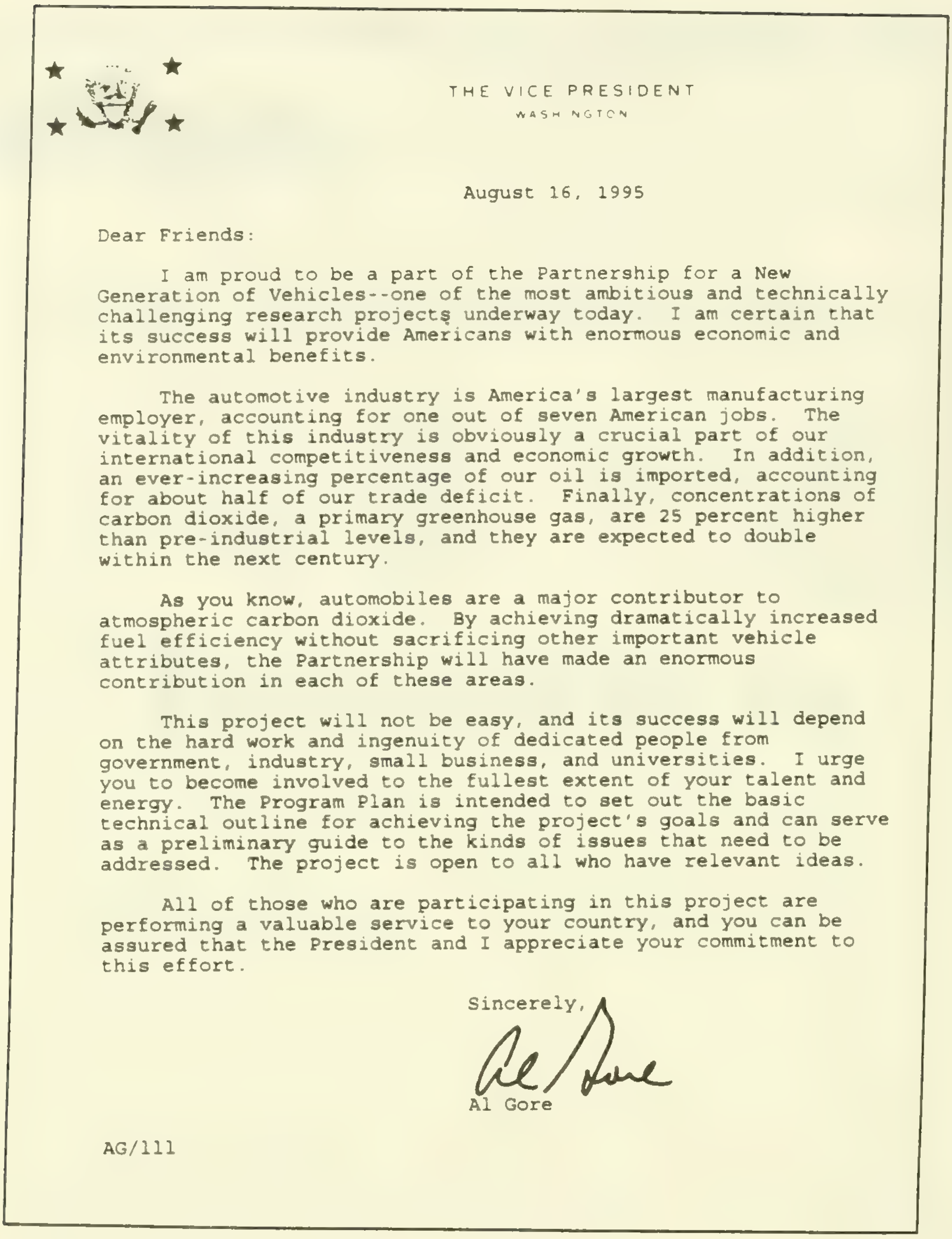


THE VICE PRESIDENT
WASHINGTON

August 16, 1995

Dear Friends:

I am proud to be a part of the Partnership for a New Generation of Vehicles--one of the most ambitious and technically challenging research projects underway today. I am certain that its success will provide Americans with enormous economic and environmental benefits.

The automotive industry is America's largest manufacturing employer, accounting for one out of seven American jobs. The vitality of this industry is obviously a crucial part of our international competitiveness and economic growth. In addition, an ever-increasing percentage of our oil is imported, accounting for about half of our trade deficit. Finally, concentrations of carbon dioxide, a primary greenhouse gas, are 25 percent higher than pre-industrial levels, and they are expected to double within the next century.

As you know, automobiles are a major contributor to atmospheric carbon dioxide. By achieving dramatically increased fuel efficiency without sacrificing other important vehicle attributes, the Partnership will have made an enormous contribution in each of these areas.

This project will not be easy, and its success will depend on the hard work and ingenuity of dedicated people from government, industry, small business, and universities. I urge you to become involved to the fullest extent of your talent and energy. The Program Plan is intended to set out the basic technical outline for achieving the project's goals and can serve as a preliminary guide to the kinds of issues that need to be addressed. The project is open to all who have relevant ideas.

All of those who are participating in this project are performing a valuable service to your country, and you can be assured that the President and I appreciate your commitment to this effort.

Sincerely,

Al Gore

Al Gore

AG/111

TABLE OF CONTENTS

LISTS OF FIGURES AND TABLES ii

EXECUTIVE SUMMARY ES-1

1.0 INTRODUCTION AND BACKGROUND 1-1

2.0 DEVELOPMENT OF THE PARTNERSHIP 2-1

3.0 GOAL 1 CONSIDERATIONS 3-1
- 3.1 Description of Potential Research Areas 3-1
  - 3.1.1 Design for Manufacturing: Virtual Manufacturing and High-Performance Computing 3-2
  - 3.1.2 Rapid Prototyping and Intelligent Processes 3-2
  - 3.1.3 Agile/Flexible Manufacturing 3-3

4.0 GOAL 2 CONSIDERATIONS 4-1
- 4.1 Description of Potential Research Areas 4-1

5.0 GOAL 3 CONSIDERATIONS 5-1
- 5.1 The Technology Challenge 5-2
- 5.2 Description of Potential Research Areas 5-4
  - 5.2.1 Advanced Lightweight Materials and Structures 5-4
  - 5.2.2 Energy Conversion Systems 5-5
  - 5.2.3 Energy Storage Technologies 5-7
  - 5.2.4 Energy Efficient Electric Systems 5-8
  - 5.2.5 Waste Heat Recovery 5-8

6.0 INTERRELATIONSHIP AND INTEGRATION OF GOALS 6-1

7.0 MILESTONES AND PRIORITIZATION OF TASKS 7-1

8.0 MANAGEMENT PLAN 8-1
- 8.1 Operating Roles 8-1
- 8.2 Federal Agencies 8-2
- 8.3 Major Domestic Automakers 8-3

9.0 RESOURCES AND FUNDING 9-1

10.0 PARTICIPATION IN PNGV 10-1

APPENDICES

- PNGV: Operational Steering Group A-1
- PNGV: Technical Task Force, Executive Committee, Technical Directorate, and Interagency Support Group B-1
- PNGV: Other Supporting Groups C-1
- Glossary of Acronyms D-1

LIST OF FIGURES

ES-1. The Partners in PNGV ES-4
ES-2. PNGV Management Organization ES-5
ES-3. Schedule for Technology Selection ES-6

1-1. PNGV Participants 1-2

2-1. PNGV Organization and Management Structure 2-1

5-1. Energy Distribution in a Mid-Size Vehicle 5-3
5-2. Achieving “3X” Fuel Economy Requires Major Improvements in Powertrain and Vehicle Characteristics 5-4

6-1. PNGV Mutually Supportive and Interactive Goals 6-1

7-1. Milestones and Prioritization of Tasks 7-1

LIST OF TABLES

ES-1. Parameters for the New Generation of Vehicles with up to Triple Fuel Efficiency ES-3

8-1. Industry Consortia Related to PNGV Research Goals 8-4

9-1. Means for Cooperative Government Programs with Auto Industry 9-1

Executive Summary

Background

On September 29, 1993, President Clinton and the Chief Executive Officers of the major domestic automakers (Chrysler, Ford, and General Motors) announced the formation of the Partnership for a New Generation of Vehicles (PNGV). The long-term goal of PNGV is to develop vehicles that will deliver up to three times today's fuel efficiency (80 miles per gallon or BTU equivalent[1]) and cost no more to own and operate than today's comparable vehicles. At the same time, this new generation of vehicles should maintain the size, utility and performance standards of today's vehicles (i.e., the 1994 Chrysler Concorde, Ford Taurus, and Chevrolet Lumina) and meet all mandated safety and emission requirements.

Potential Benefits

The PNGV will lead to significant energy, environmental, and economic benefits to the nation. In 1993, the nation imported nearly 50 percent of its oil at a cost of greater than $40 billion. With a growing population and continued increases in travel, a significant improvement in vehicle fuel efficiency would be a major step toward lessening our reliance on foreign oil supplies and reducing associated balance-of-trade deficits.

The U.S. automobile manufacturing industry is an integral part of the nation's economy, accounting for one out of seven U.S. jobs and 4.5 percent of the gross national product. The development of a new generation of vehicles will improve U.S. competitiveness by establishing the capability for technical leadership in the production of competitively priced, high fuel efficiency, and low-emission automobiles. Improvements in advanced manufacturing techniques that shorten product development times and lower costs, as well as improve product quality and durability, are essential to transfer new technologies to the marketplace affordably.

The PNGV represents a departure from the historical, primarily regulatory relationship between government and the U.S. automobile industry. The current U.S. price of oil does not encourage consumer demand for high efficiency automobiles. Government support of long-term research and development (R&D) for the development of fuel efficiency technologies is necessary to spur activity and accelerate progress in the absence of market pull. The continued leadership of the U.S. automobile industry is essential to target the results of joint research and development to commercial vehicle requirements.

---

[1] If an alternative source of energy is used, the goal will be up to 80 miles per British Thermal Unit (BTU) equivalent of a gallon of gasoline (114,132 BTUs).

Objectives and Goals

PNGV is structured to achieve three mutually supportive, interactive goals:

1) **Significantly improve national competitiveness in manufacturing.**
Improve the productivity of the U.S. manufacturing base by significantly upgrading U.S. manufacturing technology, including the adoption of agile and flexible manufacturing and the reduction of cost and lead times, while reducing the environmental impact and/or improving product quality.

2) **Implement commercially viable innovations from ongoing research in conventional vehicles.**
Pursue technology advances that can lead to improvements in the fuel efficiency and reductions in the emissions of standard vehicle designs, while pursuing advances to maintain safety performance. Research will focus on technologies that reduce the demand for energy from the engine and drivetrain. Throughout the research program, the industry has pledged to apply those commercially viable technologies resulting from this research that would be expected to significantly increase vehicle fuel efficiency and improve emissions.

3) **Develop vehicles that can achieve up to three times the fuel efficiency of comparable 1994 family sedans.**
Increase vehicle fuel efficiency to up to three times that of the average 1994 Concorde/Taurus/Lumina automobiles with equivalent cost of ownership adjusted for economics.

Vehicle Parameters

As described in the Partnership's Declaration of Intent, PNGV will pursue the development of a revolutionary class of fuel-efficient, environmentally friendly, commercially viable vehicles that meet or exceed safety and emission requirements. Specific vehicle parameters are listed in Table ES-1.

The Partnership's target is to develop a concept vehicle by 2000 and a production prototype by 2004. This ten-year time frame for the PNGV represents an extremely rapid development effort to produce a revolutionary change in automotive transportation.

Table ES-1. Parameters for the New Generation of Vehicles with up to Triple Fuel Efficiency

Vehicle Attributes	Parameters
Acceleration	0 to 60 miles per hour in 12 seconds
Number of Passengers	up to 6
Operating Life	100,000 miles (minimum)
Range	380 miles on 1994 Federal Drive Cycle
Emissions	Meet or exceed EPA Tier II
Luggage Capacity	16.8 cubic feet, 200 pounds
Recyclability	80 percent
Safety	Meet safety requirements*
Utility, Comfort, Ride & Handling	Equivalent to current vehicles
Purchase & Operating Cost	Equivalent when adjusted for economics

*Federal Motor Vehicle Safety Standards (FMVSS)

Key Research Areas

In 1994, the auto industry identified the areas in which significant innovations are needed to meet PNGV goals:

- Reduced vehicle weight,
- More efficient powertrains,
- Reduced parasitic losses.

A critical element in meeting the technical challenges in these areas will be the development of manufacturing processes that are capable of quickly delivering high quality and volume at low cost.

Participants in the Technical Program

The Partnership for a New Generation of Vehicles was formed by the Federal Government and the United States Council for Automotive Research (USCAR); the latter represents the American auto companies (Chrysler, Ford, and General Motors). Government members of the partnership include the Department of Commerce (DOC), which has been designated as the lead agency, Department of Defense (DOD), Department of Energy (DOE), Department of Interior (DOI), and Department of Transportation (DOT), as well as the Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF). Other participants in the PNGV R&D activities include industrial suppliers, universities, commercial R&D institutions, and entrepreneurs. Figure ES-1 summarizes the relationship among the various partners in PNGV.

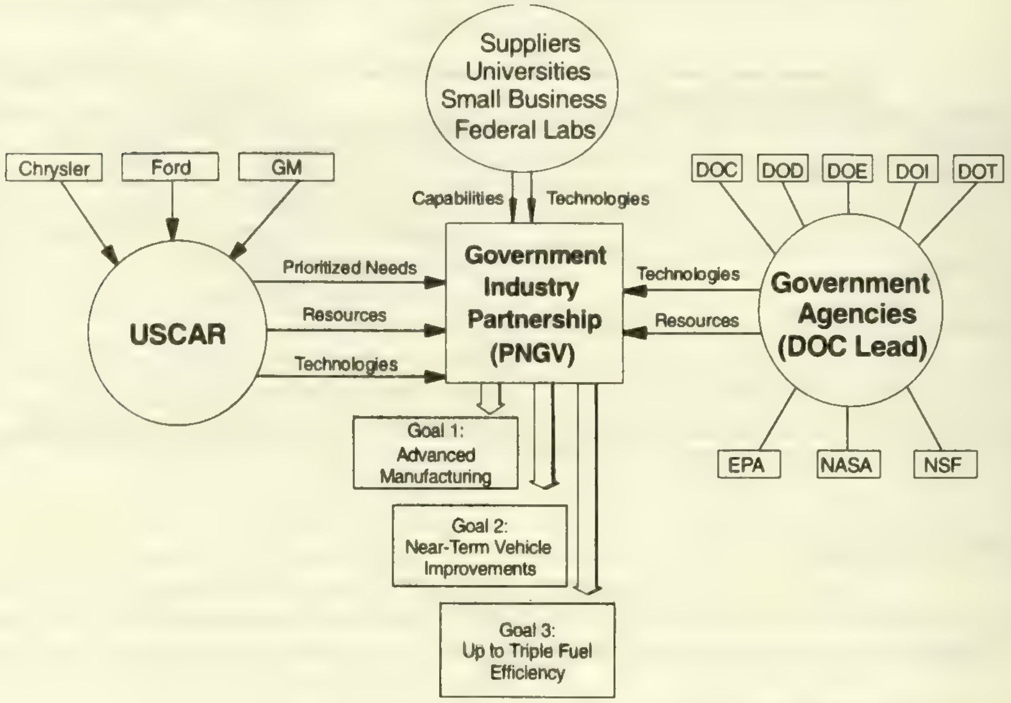


Figure ES-1. The Partners in PNGV

Technology Management Process

The industry and government teams will jointly conduct strategic planning, determine technical requirements, identify needed resources, establish milestones, and monitor progress toward achieving the three stated goals. Both government and industry are represented in the two main structural bodies of PNGV: the PNGV Operational Steering Group, which provides policy planning and direction, and the PNGV Technical Task Force, which directs the technical work. Chairmanship of the Steering Group rotates between government and industry. The management structure is illustrated in Figure ES-2.

The PNGV Operational Steering Group is responsible for

- Strategic planning,
- Program review and prioritization,
- Availability of program resources and funding,
- Coordination of legal and public affairs functions, and
- Direction to the Technical Task Force.

Government members include senior officials from DOC, DOD, DOE, DOI, DOT, EPA, NASA, NSF, the Office of the Vice President (OVP), Office of Science and Technology Policy (OSTP), Office of Management and Budget (OMB), National Economic Council (NEC), and the Council for Environmental Quality (CEQ). When government holds the chairmanship, this position is held by the Under Secretary for Technology of the Department of Commerce. The industrial members are Vice Presidents from Chrysler, Ford, and General Motors, who rotate as chairs from industry, the USCAR Executive Director, and the supporting PNGV directors from each company.

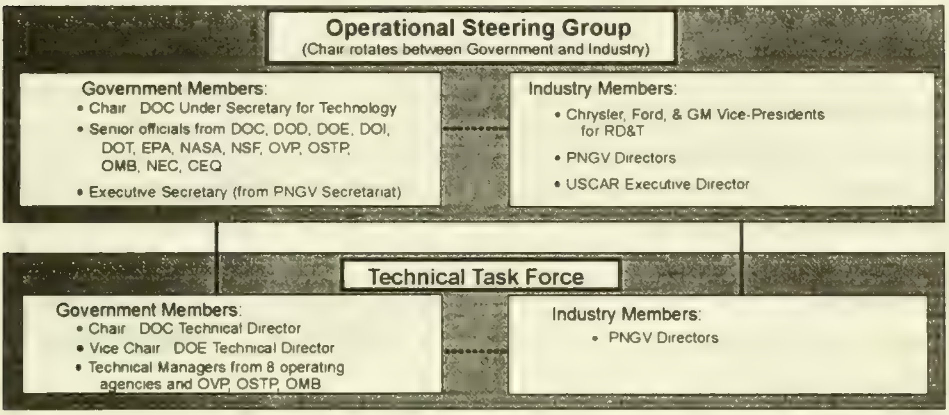

Operational Steering Group
(Chair rotates between Government and Industry)
Government Members:
• Chair DOC Under Secretary for Technology
• Senior officials from DOC, DOD, DOE, DOI, DOT, EPA, NASA, NSF, OVP, OSTP, OMB, NEC, CEQ
• Executive Secretary (from PNGV Secretariat)
Industry Members:
• Chrysler, Ford, & GM Vice-Presidents for RD&T
• PNGV Directors
• USCAR Executive Director
Technical Task Force
Government Members:
• Chair DOC Technical Director
• Vice Chair DOE Technical Director
• Technical Managers from 8 operating agencies and OVP, OSTP, OMB
Industry Members:
• PNGV Directors

Figure ES-2. PNGV Management Organization

The Technical Task Force is responsible for

- Technical planning, development, and implementation;
- Project management;
- Coordination of technical expertise among government and industry; and
- Communication of progress to the Operational Steering Group.

The Technical Task Force reports to the PNGV Operational Steering Group. The government members of the Technical Task Force include technology managers from each of the eight operating agencies and from OVP, OSTP, and OMB. The Industry Technical Task Force consists of the PNGV directors from Chrysler, Ford, and General Motors.

The technical direction for PNGV is continuously evolving under the guidance of the PNGV Technical Task Force. To produce a prototype of a high-efficiency vehicle by 2004, several promising, high-risk research and development programs are being pursued simultaneously. This multi-pronged approach will enhance the probability of achieving the needed technology breakthroughs. Technology development efforts will narrow at the end of fiscal year 1997, when technologies will be selected for additional developmental work and incorporation into concept vehicles. A further narrowing will occur around 1999-2000 as manufacturing developments are assessed and selected for use in the design and manufacture of production prototype vehicles. Figure ES-3 illustrates the timing of critical junctures when progress in the development of different technologies will be evaluated against milestones, after which technologies will be selected for further intensive development and potential inclusion in the PNGV breakthrough vehicles.

The auto industry has outlined the technical challenges and R&D opportunities for the most promising technologies in a "living document" entitled *PNGV Technical Roadmap.*

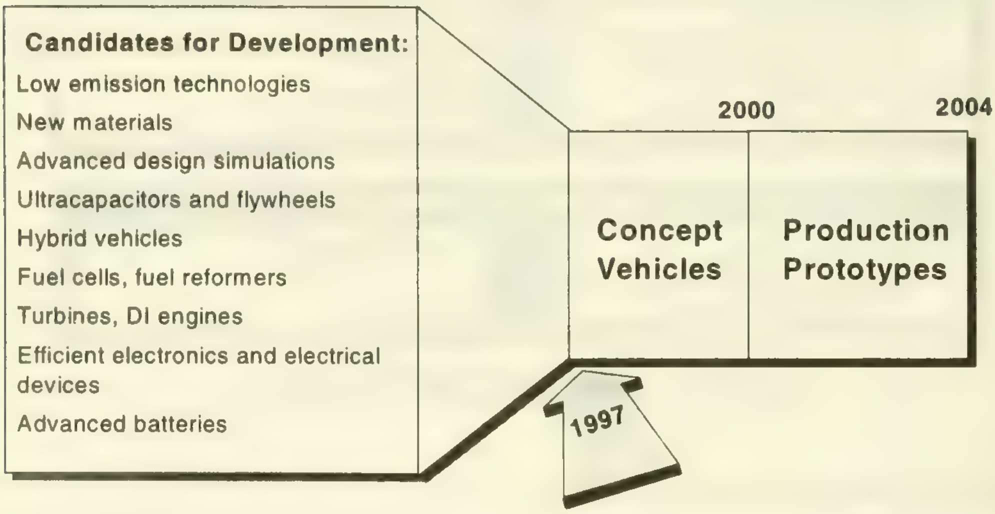

Candidates for Development:
Low emission technologies
New materials
Advanced design simulations
Ultracapacitors and flywheels
Hybrid vehicles
Fuel cells, fuel reformers
Turbines, DI engines
Efficient electronics and electrical devices
Advanced batteries
2000
2004
Concept Vehicles
Production Prototypes
1997

Figure ES-3. Schedule For Technology Selection

Leveraging of Ongoing Government and Industry Programs

This aggressive program schedule is made feasible through the leveraging of ongoing government and industry R&D programs. Prior to the announcement of the PNGV, the Federal Government and the automotive manufacturers and their suppliers had entered into cooperative research programs, and additional government-sponsored research was already being conducted in government laboratories and universities. Technology development was particularly prominent in the areas of innovative powertrains (hybrid vehicles, gas turbines, and fuel cells), lightweight materials, and energy storage devices (such as ultracapacitors, flywheels, and batteries). Many of these ongoing R&D programs originally envisioned a slower pace of development (and consequently, lower annual funding) than is needed to meet PNGV goals, but the "running start" provided by these pre-PNGV R&D programs will be vital to achievement of the PNGV goals within the allotted time.

In addition to government-assisted R&D, the automotive manufacturers maintain both proprietary and non-proprietary programs in advanced technology research in order to assure their competitive positions. Proprietary research contributions will increase as the PNGV program moves through the development of concept and production prototype vehicles.

Public Participation

Other organizations and individuals that can make an important and relevant contribution toward the attainment of the established objectives may participate in the programs and projects defined by PNGV. One objective of the program is to coordinate the resources and efforts of the Government, domestic auto industry, supplier community, universities, and individual entrepreneurs. Arrangements that bring users and suppliers of technology together into stable, long-term relationships can help to overcome the costs and risks associated with moving new technologies into the market, especially technologies with multiple applications. The specific contributions that PNGV is seeking from outside participants are described in a document entitled *Inventions Needed for PNGV*. Copies of this document and additional information about PNGV may be obtained by contacting the Government PNGV Secretariat at the address shown below. PNGV information may also be obtained through the World Wide Web Homepage located at **http://picard.aero.hq.nasa.gov/index.html.**

PNGV Secretariat
U.S. Department of Commerce
Herbert Clark Hoover Building, Room 4845
14th Street and Constitution Avenue, N.W.
Washington, D.C. 20230
Phone: 202-482-6260

1.0 INTRODUCTION AND BACKGROUND

On September 29, 1993, President Clinton and Vice President Gore joined with the Chief Executive Officers of the major domestic automakers to announce the formation of a historic new partnership aimed at strengthening U.S. competitiveness by developing technologies for a new generation of vehicles. The long-term goal of the Partnership for a New Generation of Vehicles is to develop vehicles that will deliver up to three times the fuel efficiency and cost no more to own and operate than comparable 1994 family sedans (i.e., the 1994 Chrysler Concorde, Ford Taurus, and Chevrolet Lumina). At the same time, the new vehicles must provide the same performance, interior space, and utility as comparable 1994 vehicles and meet all applicable safety and emissions requirements.

Under the auspices of the partnership, industry and government engineering teams have launched groundbreaking research and development (R&D) efforts to attain three specific, but interrelated, goals:

Goal 1, Significantly improve national competitiveness in manufacturing - Improve the productivity of the U.S. manufacturing base by significantly upgrading U.S. manufacturing technology, including the adoption of agile and flexible manufacturing and the reduction of cost and lead times, while reducing the environmental impact and/or improving product quality.

Goal 2, Implement commercially viable innovations from ongoing research in conventional vehicles - Pursue technology advances that can lead to improvements in the fuel efficiency and reductions in the emissions of standard vehicle designs, while pursuing advances to maintain safety performance. Research will focus on technologies that reduce the demand for energy from the engine and drivetrain. Throughout the research program, the industry has pledged to apply those commercially viable technologies resulting from this research that would be expected to significantly increase vehicle fuel efficiency and improve emissions.

Goal 3, Develop vehicles that can achieve up to three times the fuel efficiency of comparable 1994 family sedans - Increase vehicle fuel efficiency to up to three times that of the average 1994 Concorde/Taurus/Lumina automobiles with equivalent cost of ownership adjusted for economics.

There are a number of economic, energy, and environmental considerations concerning why it is in the best interest of the United States to develop energy-efficient, low-emission vehicles in an accelerated timeframe.

- Currently, more than 13 million people are employed in motor vehicle-related industries in the United States; over 2 million of these individuals are employed directly by the U.S. automakers and their suppliers and dealers.

- The domestic industry accounts for 4.5 percent of the gross domestic product.

- Ground transportation accounts for one-fourth of the energy demand in the United States.

- The introduction of this next generation of vehicles into the on-road fleet promises to reduce gasoline consumption and emissions of carbon dioxide.

- Additional environmental gains can be expected as improved manufacturing processes enable a higher percentage of recycling, reduce scrap rates, and minimize waste by improved design.

The development of the breakthrough technologies required to achieve the PNGV goals cannot be supported by either government or industry alone; therefore, public policy considerations led to a partnership between government and industry to address this challenge.

The Partnership for a New Generation of Vehicles (PNGV) will address these goals through a shared commitment by the government and the United States Council for Automotive Research (USCAR), which consists of Chrysler, Ford, and General Motors. This collaborative effort coordinates the unique strengths and research and development capabilities of the national laboratories, universities, industry, and their broad network of suppliers. Participation in the programs and projects of PNGV will be open to other organizations and individuals that can make a significant contribution toward attainment of the defined goals (see Chapter 10, Public Participation). Figure 1-1 shows the major PNGV participants.

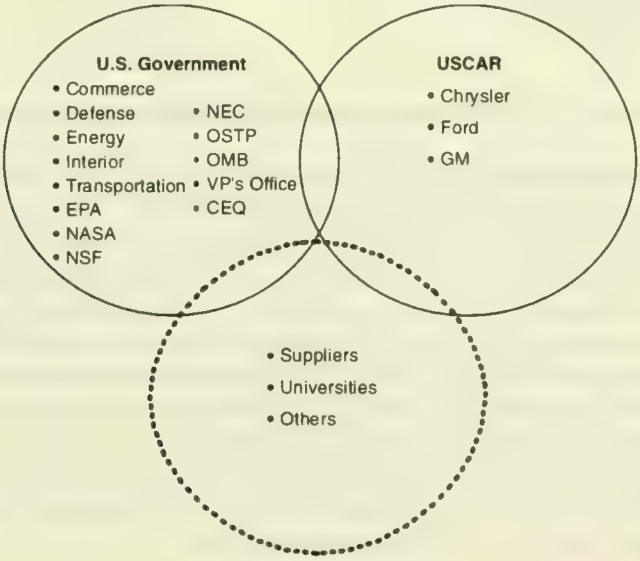
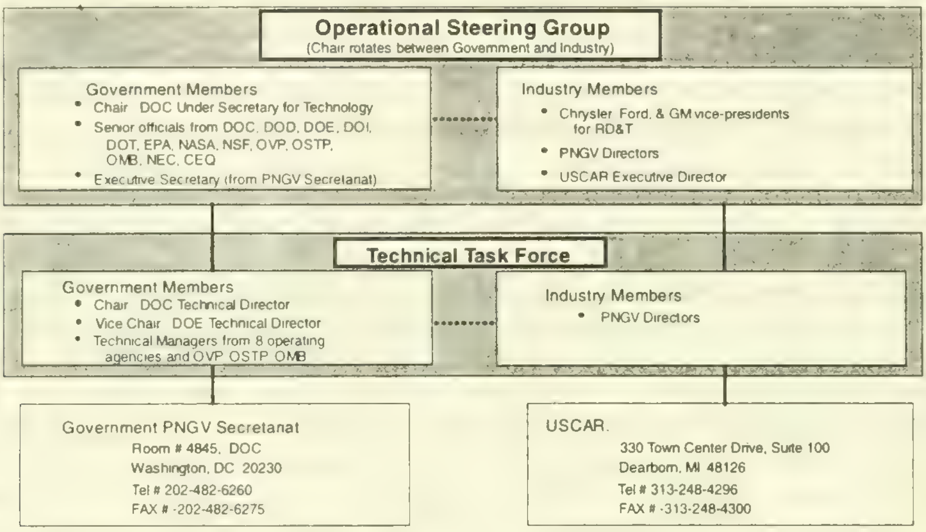


Figure 1-1. PNGV Participants

2.0 DEVELOPMENT OF THE PARTNERSHIP

The organization and operation provide for shared leadership and ensures solid technical guidance for this important program. Organizationally, this partnership is a coordinated effort between the Federal Government and the USCAR. USCAR was formed by the major domestic automakers to develop technology in selected pre-competitive research areas. It is anticipated that this partnership will set the standard for future joint government/industry ventures. The overall organization and management structure for this partnership is illustrated in Figure 2-1.


Operational Steering Group
(Chair rotates between Government and Industry)
Government Members
• Chair DOC Under Secretary for Technology
• Senior officials from DOC, DOD, DOE, DOI, DOT, EPA, NASA, NSF, OVP, OSTP, OMB, NEC, CEQ
• Executive Secretary (from PNGV Secretariat)
Industry Members
• Chrysler Ford, & GM vice-presidents for RD&T
• PNGV Directors
• USCAR Executive Director
Technical Task Force
Government Members
• Chair DOC Technical Director
• Vice Chair DOE Technical Director
• Technical Managers from 8 operating agencies and OVP OSTP OMB
Industry Members
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FAX # -313-248-4300

Figure 2-1. PNGV Organization and Management Structure

The **Operational Steering Group** is the policy and decision-making arm of the partnership. The Under Secretary for Technology of the Department of Commerce serves as the Chair of the Government Operational Steering Group which includes senior officials from each of the participating agencies and offices: the Department of Commerce (DOC), the Department of Defense (DOD), the Department of Energy (DOE), the Department of Interior (DOI), the Department of Transportation (DOT), the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the Office of the Vice President (OVP), the Office of Science and Technology Policy (OSTP), the Office of Management and Budget (OMB), the National Economic Council (NEC), and the Council for Environmental Quality (CEQ). The industry Operational Steering Group is comprised of Vice Presidents from Chrysler, Ford, and General Motors, who rotate the chair responsibilities, industry PNGV directors, and the USCAR executive director.

The **Technical Task Force**, which reports to the Operational Steering Group, also has representatives from both government and industry. The Government Technical Task Force is composed of technical managers from the eight operational agencies, as well as from OVP, OSTP, and OMB. The Industry Technical Task Force is made up of the PNGV directors of the major domestic automakers.

Peer Review

The agreement between the government and the U.S. auto industry establishing PNGV called for a Peer Review on technologies selected for research and progress achieved. The first Peer Review by experts in technology and R&D management was held on August 22 - 25, 1994. The findings were published in the *Review of the Research Program of the Partnership for a New Generation of Vehicles*, by the National Research Council.

3.0 GOAL 1 CONSIDERATIONS

Goal 1 - Significantly improve national competitiveness in manufacturing.

Improve the productivity of the U.S. manufacturing base by significantly upgrading U.S. manufacturing technology, including the adoption of agile and flexible manufacturing and the reduction of cost and lead times, while reducing the environmental impact, and/or improving product quality.

Manufacturing technologies are critically important to ensuring competitiveness in today's marketplace and are essential to producing the new generation of vehicles.

Areas of focus for the achievement of Goal 1 will include the following:

- Improving the design and development processes to cut lead times and costs,
- Developing new manufacturing and vehicle assembly systems that will increase productivity, and
- Assuring the ability to integrate and validate technologies as systems.

Research and development may address the following specific technology areas: flexible/agile tooling and equipment that can reduce costs and the time for product changes; more sophisticated computer simulation systems for testing complex research designs and their effects on characteristics such as rolling resistance and braking; and methods for designing and analyzing strength characteristics of composite structures.

Development and deployment of these new manufacturing technologies will increase U.S. competitiveness in general and will strengthen the U.S. auto industry in particular. Research in this area is also required to assure the manufacturability of the advanced technology necessary to address Goal 3. Research into these alternative and emerging technologies will also improve our understanding of the role they might play in the future of manufacturing and U.S. competitiveness. Their acceptance and implementation will be fully dependent upon a net positive contribution.

3.1 Description of Potential Research Areas

Research areas for the achievement of Goal 1 fall into two categories:

- Generic manufacturing enhancements – "generic" design and manufacturing technologies that reduce the cost and time to bring product innovations to the market and are applicable to both current vehicle designs and the PNGV breakthrough vehicle.

- Enabling technologies for the breakthrough vehicle – manufacturing technologies that enable affordable, high-quality, mass production of new technologies used in the design of the breakthrough vehicle.

The following three areas will be pursued to meet Goal 1:

- Design for Manufacturing,
- Rapid Prototyping and Intelligent Processes, and
- Agile/Flexible Manufacturing.

Specific project areas have been identified to advance precompetitive, generic capabilities; these projects will be pursued in collaboration to leverage resources and speed progress.

3.1.1 Design for Manufacturing: Virtual Manufacturing and High-Performance Computing

Developments in the arena of design for manufacturing will focus on techniques that simplify product fabrication and assembly. These techniques could include the application of virtual manufacturing and high-performance computing technologies.

Through virtual manufacturing, a design can be rapidly conceived, recorded, analyzed, and numerically checked before any actual manufacturing takes place. Virtual manufacturing can be used to best advantage when combined with high-performance computing to simulate the flow of parts, tasks, and assemblies through the factory. This allows every step of the manufacturing process to be computer simulated and optimized before any investment is made in prototyping, processing equipment, the physical plant, or personnel.

High-performance computing allows the rapid and seamless communication of information among the design, analysis, and test modules. It can be applied to the analysis and understanding of the factory process itself to optimize the utilization of tools and control the delivery of parts and supplies. Through increased computational capabilities (such as massively parallel computing), better computer networking, and lower computing costs, it is possible to analyze complex design trade-offs quickly and accurately while minimizing the time-consuming, iterative cycle of design, analysis, prototyping, testing, and redesign.

3.1.2 Rapid Prototyping and Intelligent Processes

Direct transfer of computer-aided design parameters to manufacturing machinery results in time and cost savings. Toward this end, rapid prototyping technologies could facilitate the translation of new designs into tangible hardware.

Seamless techniques for communicating design descriptions from the drafting room to the manufacturing floor are essential. New prototyping machinery using technologies such as stereolithography and laser sintering make it possible to rapidly produce solid models, but further improvement is necessary.

Process models being developed with computer-based tools also support the development of rapid manufacturing processes. In addition, intelligent processes for casting, forming, machining, and joining are constantly evolving, and promise to not only reduce the need for subsequent processing steps but also to reduce scrap materials and waste.

The automobile manufacturing industry is a leader in the use of contemporary technologies in rapid prototyping and intelligent processes. Further benefits could derive from additional research and development in the following areas:

- Models of casting, sheet forming, induction hardening, and thermal spraying processes;
- Techniques for residual stress and spring-back calculations;
- Analysis for molding of fiber-composite panels;
- Design of high-accuracy tooling;
- Prototype component fabrication using polymer-based stereolithography and laser sintering;
- Sensors for manufacturing process control; and
- Dynamic modeling of mechanical and chemical process systems to optimize plant designs.

3.1.3 Agile/Flexible Manufacturing

Agile manufacturing provides for rapid response to fluctuations in requirements while providing high-quality, highly customized products. It integrates product definitions, process knowledge, and marketing information to ensure that the right products get to the customers at the right times, and at costs competitive with today's norms. A key to this technology is the integration of the tooling and manufacturing processes, which allows for rapid tooling design, fabrication, and interchange. Advanced sensors, intelligent controls, and innovative actuators are important components of computer-controlled and programmable manufacturing machinery.

Government laboratories, a variety of supplier companies, and universities may augment the auto industry in furthering the development of agile manufacturing technologies. Cooperative programs could expedite the availability of advanced agile manufacturing capability. Examples of ongoing projects under cooperative research and development agreements (CRADAs) in this area include the following government-sponsored projects:

- Technologies Enabling Agile Manufacturing (TEAM),
- Enhancement of Manufacturing Operations Using Nondestructive Evaluation,
- Simulation/Analysis of Robotic Assembly Devices and Fixtures, and
- Cost-Effective Ceramic Machining.

4.0 GOAL 2 CONSIDERATIONS

GOAL 2 - Implement commercially viable innovations from ongoing research in conventional vehicles.

Pursue technology advances that can lead to improvements in the fuel efficiency and reductions in the emissions of standard vehicle designs, while pursuing advances to maintain safety performance. Research will focus on technologies that reduce the demand for energy from the engine and drivetrain. Throughout the research program, the industry has pledged to apply those commercially viable technologies resulting from this research that would be expected to significantly increase vehicle fuel efficiency and improve emissions.

In the near term, research that supports Goal 2 will build on initiatives already in progress in the industry. For the period beyond the planning horizon (judged to be 2000 and beyond), collaborative research between USCAR and the government will be most significant. For the near term timeframe, industry plans to prioritize areas of research that have greater potential for fuel-efficiency improvement in conventional vehicle designs.

4.1 Description of Potential Research Areas

To maximize fuel efficiency and minimize emissions, the combustion process must be modeled with sufficient accuracy to predict energy release and pollutant formation. Furthermore, diagnostics are required to assure that the desired processes are occurring during operation. Other key factors in addressing Goal 2 include the design and fabrication of components that can operate in the more severe friction and wear environments that will occur in the new generation of vehicles. Higher temperatures, higher cylinder pressures, greater loads and stresses, lower oil viscosity, and more chemically reactive fuels will increase the wear on piston rings, cylinder liners, valves, valve stems, fuel injectors, cams, bearings, and other components. Therefore, a better understanding is needed of how friction, wear, and lubrication affect materials, components, and engine systems. This knowledge will provide the basis for the development of advanced lubricants and cost-effective processes for surface modification to reduce friction and increase the wear and corrosion resistance of engine components.

Research is also needed on materials and technologies that reduce the demand for energy from the engine and drivetrain. Toward this end, work is needed to improve aerodynamics and reduce rolling resistance. These activities contribute to Goal 2 in the near term and to Goal 3 in the longer term.

Pre-competitive research and development for materials is conducted under the direction of USCAR's Automotive Materials Partnership (USAMP) and the Automotive Composites Consortium (ACC). Efforts to advance material applications and manufacturing processes are focused on the pre-competitive objectives of the characterization of hardware and manufacturing processes and of the properties of materials. The mass reduction and performance targets for the development of conventional materials are the same as those for advanced materials for Goal 3.

An important existing initiative under Goal 2 in the Engine Support System Technology (ESST) Program, which is a cooperative effort between government and industry through the USCAR Low Emissions Partnership (LEP). This program has placed a high priority on the development of oxides of nitrogen (NO_x) catalysts to enable the use of lean burn and ultra-lean burn internal combustion engines. Other new technology areas identified for potential research and development include on-board vehicle diagnostic systems, enhanced air-fuel mixture preparation strategies, advanced emissions sensors, and rapid heat-up catalysts.

5.0 GOAL 3 CONSIDERATIONS

GOAL 3 - **Develop vehicles that can achieve up to three times the fuel efficiency of comparable 1994 family sedans.**

> *Increase vehicle fuel efficiency to up to three times that of the average 1994 Concorde/Taurus/Lumina automobiles with equivalent cost of ownership adjusted for economics.*

Research undertaken in pursuit of this goal is to be guided by the following specific assumptions:

- Fuel efficiency will be measured in terms of miles per equivalent gallon of gasoline. If an alternative source of energy is used, the goal will be miles per British Thermal Unit (BTU) equivalent of a gallon of gasoline (or 114,132 BTUs). (Also, it is assumed that use of an alternative energy source will require separate government/industry activities and direction regarding BTU measurement and infrastructure challenges.)

- Vehicles will satisfy Tier II emissions standards at the default levels of 0.125 g/mile of hydrocarbons (HC), 1.7 g/mile of carbon monoxide (CO) and 0.2 g/mile of oxides of nitrogen (NO_x) at 100,000 miles while complying with other *Clean Air Act* requirements.

- The target vehicles will meet the efficiency improvement goal while meeting present and future Federal Motor Vehicle Safety Standards (FMVSS).

- Target vehicles will be at least 80 percent recyclable, up from the 75 percent industry average today.

- A concept vehicle should be available in approximately six years and a production prototype in approximately ten years.

The following characteristics are to be used in defining comparable 1994 family sedans:

- Family sedan function, i.e., capable of carrying up to six passengers with a comfort level equivalent to that of the 1994 Chrysler Concorde, Ford Taurus, and Chevrolet Lumina, at a fuel efficiency of up to three times the average of 26.6 mpg (unadjusted combined metro highway based on Federal Test Procedure) or 26.6 miles per 114,132 BTUs. Three times this efficiency is 80 miles per 114,132 BTUs.

- Acceleration from 0-60 mph (0-100 kph) in 12 seconds (at curb weight, with 300 lbs. of passenger load and a full fuel tank).

- Luggage capacity of 16.8 cubic feet or 475 liters and load-carrying capacity equivalent to that of the comparable 1994 sedans (load carrying capacity includes up to six passengers with full fuel tank and 200 pounds of luggage).

- Operating metro-highway range of at least 380 miles (610 km) on the 1994 Federal Drive Cycle.

- Equivalent to comparable 1994 family sedans in all of the following aspects:

  - Performance in all areas, including acceleration, cruising speed, gradeability, and driveability at sea level and at higher altitudes

  - Ride and handling

  - Noise, vibration, and harshness control

  - Customer features and options, including climate control and entertainment packages

  - Total cost of ownership (with non-preferential tax treatment on a BTU basis) adjusted for economics

- Minimum useful life of 100,000 miles (160,000 km) with comparable or improved service intervals and refueling time.

- Capable of being easily produced for export and sale in major world markets.

5.1 The Technology Challenge

The distribution of energy in a current mid-size (family sedan) vehicle is shown in Figure 5-1. Note that in this typical vehicle system, only 12.6 percent of the energy turns the wheels after engine, standby, driveline, and other losses on the Federal Urban Test Cycle.

Major advances must be made in several technologies simultaneously in order to achieve an 80 mpg vehicle. Improving the fuel economy requires a three-pronged approach:

1) Convert energy more efficiently,
2) Implement regenerative braking to recapture energy, and
3) Reduce the energy demand from the vehicle.

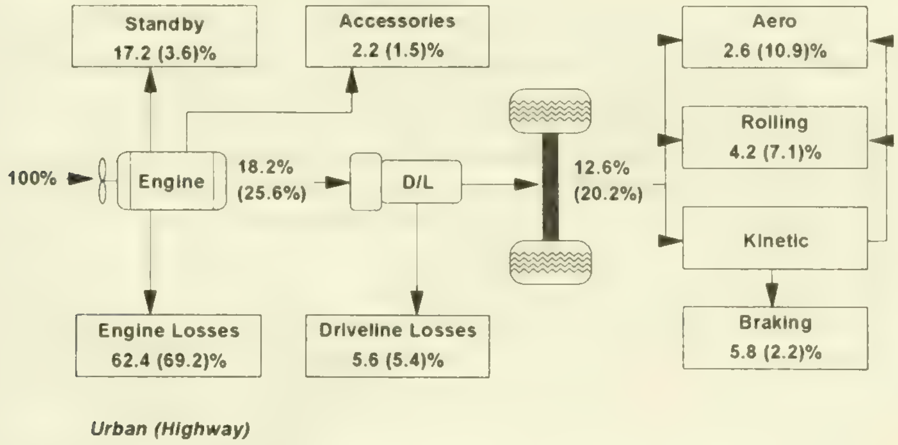

Figure 5-1. Energy Distribution in a Mid-Size Vehicle

A parametric model has been used to show the various ways in which these approaches could be combined to achieve the 80 mpg goal. Figure 5-2 illustrates the approximate "design space" for possible alternative approaches for achieving the goal.

The design space has both theoretical and practical limits. On the basis of thermal efficiencies that are practical to achieve with various heat engines, the targeted fuel economy may not be attainable through engine improvements alone. The needed thermal efficiency ranges from approximately 40 percent to 55 percent, which is twice that of today's engines. Even with advanced fuel cells, which have higher potential efficiencies than heat engines, other vehicle improvements are likely to be needed.

Even with improved engines and lighter vehicles, models show that an efficient regenerative braking system must be implemented to recover, store, and reuse energy currently lost by braking. This approach will reduce the amount of energy that must be converted from fuel, which is normally the most inefficient step of the energy cycle.

In addition to improved power converters and regenerative braking, attainment of the fuel efficiency goal will likely require a 20 percent to 40 percent reduction in the mass of today's baseline vehicles. This will require more than simple refinements to today's frame and body construction, and calls for the introduction of entirely new classes of structural materials.

Advances must also be achieved in several other vehicle technologies. Although each of these will contribute less to the overall system goal, their combined contribution may be significant. These technologies include reduced aerodynamic drag, reduced tire rolling resistance, and more efficient mechanical and electrical components.

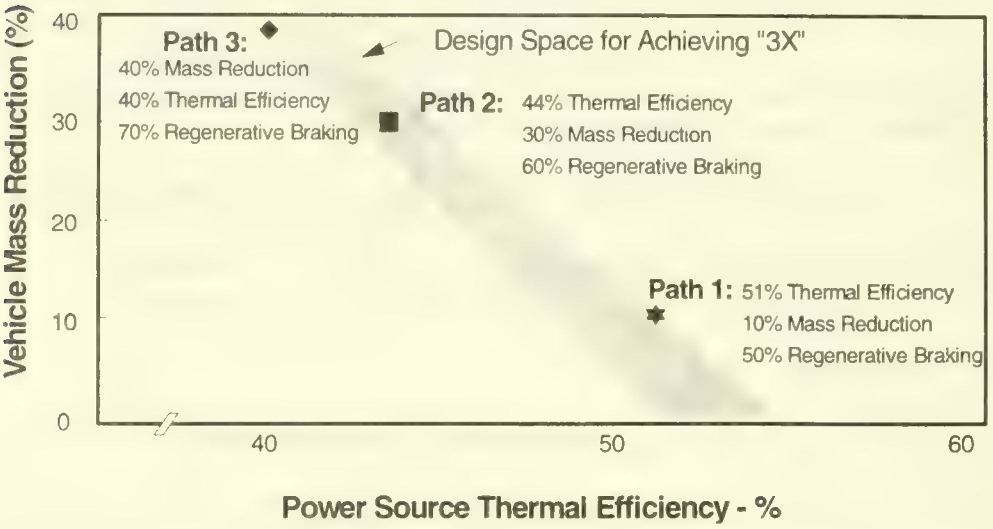

Figure 5-2. Achieving "3X" Fuel Economy Requires Major Improvements in Powertrain and Vehicle Characteristics*

*All paths include: 90 percent efficient energy storage, 76.5 percent efficient driveline, 20 percent lower rolling resistance, 30 percent lower accessories loads

5.2 Description of Potential Research Areas

In order to achieve Goal 3, research and development is needed in the technology areas leading to improvements in the vehicle and propulsion system. These technologies include advanced materials and structures; energy efficient conversion systems (e.g., advanced internal combustion engines, gas turbines, and fuel cells); energy storage devices (e.g., advanced batteries, flywheels, and ultracapacitors); more efficient electrical systems; and waste heat recovery.

5.2.1 Advanced Lightweight Materials and Structures

Lightweight materials have a direct impact on improving vehicle fuel economy. A substantial portion of fuel consumption is directly associated with a vehicle's weight, because heavier vehicles require more energy for accelerating and maintaining speed, and dissipate more braking energy for stopping. The challenge is to reduce mass while maintaining an affordable, safe structure.

The auto industry has been involved in the research and development of lightweight materials, such as aluminum, titanium, titanium aluminide, magnesium, metal matrix composites, polymers, and polymer matrix composites. However, their use has been limited because they are much more expensive to produce than conventional steel, and their recycling has proven to be a challenge. Alternatively, optimized designs using high strength steel offer the potential for weight reduction.

To address the technological challenges of PNGV, major efforts are required in the following areas: 1) enhanced processing and manufacturing techniques for lightweight metals; 2) processing and manufacturing techniques for "high tech" lightweight, high strength materials such as polymer and metal matrix composites and structural ceramics, including interfacing and joining of these materials with conventional materials; 3) recycling technology for in-plant and scrapped vehicle waste; and 4) robust methodologies for optimizing designs and reducing engineering development time. Materials R&D focuses on aluminum, magnesium, graphite-reinforced polymer composites, metal matrix composites, new applications of high-strength steels, glass-reinforced polymers, design optimization, glazing materials, and joining technologies.

5.2.2 Energy Conversion Systems

Lean Burn Internal Combustion Engines - Advanced spark-ignition and diesel engines which exhibit particularly strong fuel economy characteristics are lean burn in nature. Compared to a standard spark-ignited passenger car engine which operates near a stoichiometric condition over its entire load and speed range, lean burn engines operate nearer to an ideal air standard cycle and minimize low load pumping or throttling losses. Various evolutionary and proposed revolutionary adaptations of this class of engine hold great promise relative to meeting fuel economy targets, while achieving success in areas such as cost effectiveness, manufacturability, customer acceptance, overall performance, and emissions.

Lean burn engines that offer the potential for significant fuel gains are 1) spark-ignited, direct fuel injected, stratified-charge engines, and 2) direct fuel injected diesel engines. A number of preliminary versions of both of these engine types have been demonstrated by various government and commercial organizations but no production prototypes have yet demonstrated the efficiency and emission targets of PNGV. Projected advances in emissions aftertreatment for lean burn engines further enhances their stock relative to PNGV objectives for Goal 3.

As an example, advanced diesel engines have been run in the laboratory at significantly higher efficiencies than conventional diesel engines. The use of these engines in passenger-car size engines will require advances in areas such as: accelerated mixing and combustion, fuel injection spray pattern timing, and compliance to small bore engines.

Gas Turbines - As part of a series hybrid propulsion system, the gas turbine could maintain efficiency by operating close to the design point instead of over a wide range of conditions. A ceramic gas turbine, because of its high-temperature capability, has the potential to achieve excellent fuel efficiency while preserving its low emissions characteristics.

Government programs have made progress in making ceramic gas turbine components technically viable, especially in the difficult area of improving the strength and reliability of high-temperature, structural ceramic materials. Programs are underway to address the manufacturing of cost-effective advanced ceramics. Several of these critical high temperature ceramic components have been fabricated and successfully rig-tested in a research setting.

To improve the technological readiness of ceramic gas turbines for the new generation of vehicle, research and development objectives include the following:

- Low-cost, high-volume manufacturing of high strength structural ceramic components;
- Improved combustion systems that would comply with Tier II emission standards;
- Robust mechanical technologies and configurations; and
- Scaled down turbines (0-60 kW) for hybrid vehicles, with improved efficiency.

Fuel Cells - A fuel cell is an electrochemical device that converts the energy of a chemical reaction directly into electrical energy. Fuel cells can be clean and highly efficient, low emissions sources of electrical energy for vehicle propulsion. Fuel cells do not have a combustion process that generates airborne pollutants. In a typical fuel cell system, hydrogen and oxygen (from air) react to produce electricity, heat, and water. No electrical recharging of the fuel cell is necessary; as long as hydrogen fuel and air are supplied to the fuel cell, it continues to produce power. The hydrogen may be stored as pure gas or stored as a hydrogen-containing fuel (such as methane, methanol, or ethanol), which must then be processed (reformed) to liberate the hydrogen for consumption in the fuel cells.

Fuel cell technologies that may be appropriate for development and use in vehicle applications include the proton exchange membrane fuel cell (PEMFC) and direct methanol fuel cell (DMFC).

PEMFCs have the potential to achieve the power density required for cars but research and development are required to reduce cost and optimize performance. Development efforts on PEMFC systems for the new generation vehicle are focusing on:

- improved membrane development,
- advanced fuel cell stack designs,
- more efficient air compression systems,
- improved onboard storage technology for hydrogen,
- compact, lightweight, rapid-response fuel processors, and
- versatile water and thermal management.

For DMFCs, which are based on modifications to conventional PEMFC technologies, key aspects of the development program are focusing on:

- Developing low-cost materials and lightweight structures,
- Optimizing membranes (high-temperature stability, methanol-impermeability), and
- Improving methanol oxidation catalysts to improve anode reaction kinetics and reduce catalyst loading.

Hybrid Propulsion Systems - All of the previously-mentioned fuel converters (lean burn spark-ignition and diesel engines, gas turbines, and fuel cells) may be combined with electric drive motors and efficient energy storage devices to form hybrid propulsion systems. A hybrid propulsion system incorporating efficient conversion technologies may provide the opportunity for better energy management and utilization. Research and development is, therefore, focusing on advanced technologies that could exhibit dramatically improved energy conversion efficiencies within the timeframe of the PNGV. Major issues of emissions, system packaging, manufacturability, consumer acceptance, and cost need to be resolved.

5.2.3 Energy Storage Technologies

High-power energy storage devices that are lightweight and compact are also essential to implementing a hybrid propulsion system. These devices could provide an efficient means for storing engine output when the vehicle is coasting or stopped and also for recovering and storing the energy ordinarily dissipated as heat during braking. The energy stored could subsequently be used to supply additional power for acceleration, and the supplemental power needed by the vehicle during sustained hill climbing.

Candidate technologies that may be investigated include high-power batteries, flywheels, and ultracapacitors. Cost reduction is, of course, essential to the viability of all of these candidates.

High-Power Batteries - The specifications for the high-power batteries needed to store braking energy differ greatly from those being developed for electric vehicles. These batteries are used for power management and are required to store much less overall energy, but must operate at very high power levels. Power-to-energy ratios in the range of 5 to 20 are needed compared to only about 2 for electric vehicle batteries. Furthermore, power management batteries could be discharged and charged many times per day, therefore, battery cycle life becomes extremely important. Most battery development to date has been directed to all-electric vehicles with relatively little work conducted on high-power, multi-cycle batteries for hybrid-electric vehicles. To meet the needs of the PNGV program, developmental efforts on high-power multi-cycle batteries need to be expanded. Potential battery technologies appropriate for the program include nickel/metal hydride, nickel/hydrogen, lithium/polymer, and other bipolar batteries.

Flywheels - Prototype flywheel systems have demonstrated an installed specific energy of 5 Wh/kg and a specific power of 350 W/kg in commercial transit buses. Several experimental vehicles have been built using flywheels for automotive applications. Additional research and development efforts will focus on increasing the specific energy and reducing the cost of flywheel systems. Further, research and development offer the potential to reduce material costs, provide lightweight containment, and simplify overall system integration. Potential technical solutions include improved processing and production of high-performance fibers, wet-filament winding, in-situ or rapid curing, and multi-layer containment shielding based on low-cost metal matrix and polymer composites.

Ultracapacitors - Ultracapacitors are characterized by a high specific power, high charge/discharge energy efficiency, and excellent cycling characteristics. Ultracapacitors commercially available today have a specific energy of about 1 to 2 Wh/kg. Laboratory prototype ultracapacitors have recently been developed with a specific energy of about 2 to 5 Wh/kg and specific power of 2 to 4 kW/kg. Aerocapacitors, which are based on the use of aerogels with aqueous or organic electrolytes, have projected specific energies of 4 to 8 Wh/kg. The key technical challenges are to improve the ultracapacitor's discharge rate, its low specific energy, and to reduce costs. Research and development offers the potential to improve ultracapacitor materials such as carbon/metal fiber composites, monolith foamed carbon, foamed carbon with a binder, doped polymer layers on carbon paper, and mixed metal oxides (ceramic) on metal foil.

5.2.4 Energy Efficient Electric Systems

Today's electrical systems could benefit from reduced weight and losses in the many electrically-powered accessories on today's internal combustion engine powered vehicles.

Continuing advances in power electronics, motor design, motor controllers, and permanent magnets have made possible the development of alternating-current (ac) powertrains, which offer reduced size, weight, and improved efficiency. During the last decade, ac electric powertrain technology has been demonstrated to meet the requirements of electrically driven vehicles. Research and development will be undertaken to improve the overall efficiency of the electric driveline (controller, motor, and transmission) and the regenerative mode. Improvements will also be sought in reducing the weight of the traction drive motor and power electronics. The other remaining challenge is to achieve sizable reductions in the manufacturing costs of the electric drivetrain.

Research and development activities are focusing on power semiconductors; power management and control/energy management; advanced motors and generators (low-cost, high specific power); and models for electric motor/generator and electronics and electric devices.

5.2.5 Waste Heat Recovery

In today's vehicles, more than 60 percent of the fuel energy is lost in the exhaust and cooling system. Recovery of this energy is made difficult by the low temperatures of the waste heat streams and the absence of appropriate recovery technology. The use of lower temperature, reduced thermal mass cooling systems are shown to have a modest effect on emissions and fuel economy. The options for waste energy recovery in piston engines include bottoming cycles, turbocompounding, over-expansion devices, and thermal-to-electric energy conversion devices. However, these devices all suffer from high cost and packaging problems. These systems are not currently cost-effective because of low fuel prices. Research could be targeted at affordable technologies for efficiently recovering and utilizing exhaust energy.

6.0 INTERRELATIONSHIP AND INTEGRATION OF GOALS

The close interrelationship among PNGV's three, mutually supportive goals is illustrated in Figure 6-1. The new manufacturing technologies and approaches developed to meet Goal 1 can lead to dramatic improvements in product quality, cost, and time-to-market. These improvements in manufacturing productivity will help to assure that the cars of the future (using designs developed to meet Goals 2 and 3) are produced by U.S. industry and will benefit the U.S. economy.

The focus of Goal 2 is on near-term technological improvements, particularly in automobile efficiency, safety, and emissions. Progress in pursuit of this goal is essential for the achievement of Goal 3. At the same time, progress made in the early phases of Goal 3 can support the objectives of Goal 2. Similarly, Goal 3 will draw on the achievements toward Goals 1 and 2 as well as contribute to the technology pull in those two areas.

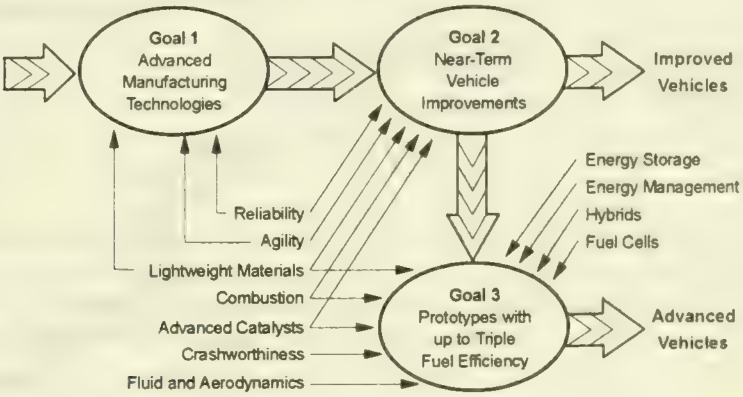

Figure 6-1. PNGV Mutually Supportive and Interactive Goals

7.0 MILESTONES AND PRIORITIZATION OF TASKS

As shown in Figure 7-1, the PNGV schedule for accomplishment of breakthrough vehicle technologies provides for an orderly progression from the development of discrete component technologies to their integration into subsystems, followed by system development and full-vehicle demonstrations.

PNGV Master Program Schedule
6/2/94

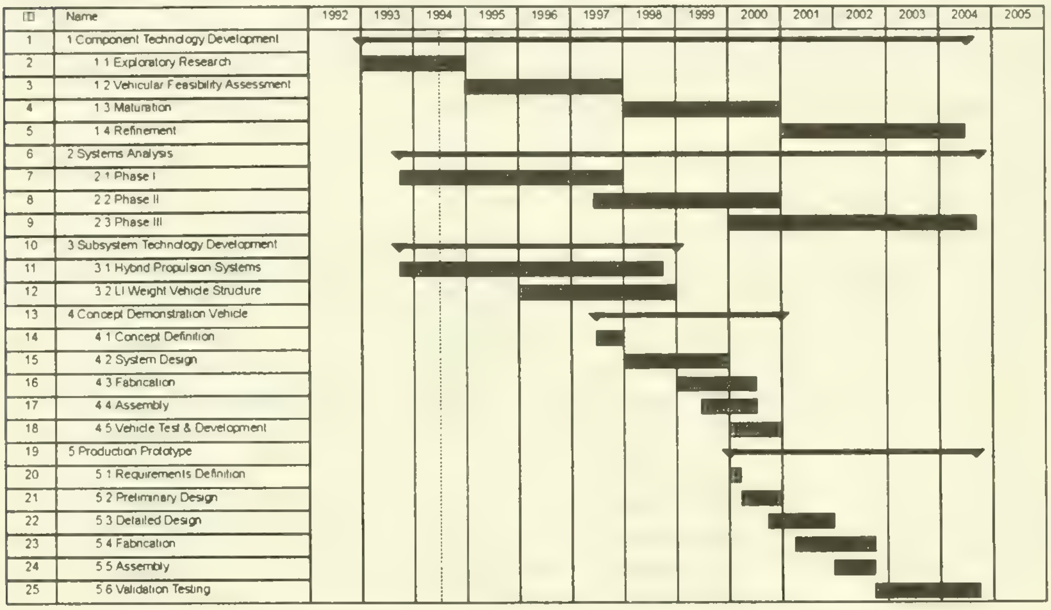

Figure 7-1. Milestones and Prioritization of Tasks

The first vehicle demonstration is called a "concept car" (see item 13 in Figure 7-1) and is intended to evaluate the engineering feasibility of the components when integrated for the first time in a total system. The second vehicle demonstration is called a "production prototype" (see item 19 in Figure 7-1) because it entails demonstration of manufacturing feasibility and must meet more rigorous product performance criteria.

PNGV's aggressive timetable for completing concept cars and production prototypes requires that the first set of component technologies be narrowed down by the end of 1997. The selection process will be based on data from representative experiments, therefore work on technologies must be accelerated as much as possible so that the various options can be considered on demonstrated merit.

Even after certain component technologies have been selected for evaluation in the vehicle-level demonstrations, they must continue to mature. It is expected that by 1997, only intermediate targets will have been met. Continued investment should be made in these technologies so that second and third generation components will become available for later demonstrations and potential incorporation into full-production vehicles.

This schedule also shows a continuing systems analysis effort to link the work on components and systems. This integration is extremely important as it will provide quantitative evaluation of the alternative components and systems. Future resource allocation will be influenced by the outcome of these rigorous systems analyses.

The last step of the planning process will be to define the technical approaches and programs needed to achieve the quantitative targets within the prescribed timeframes. Each of the targets for components can be approached in several ways. Some of the approaches have the potential to exceed the targets, although generally at higher cost and risk.

The Partnership is currently defining the specific programs needed and setting the stage for the concept vehicle demonstrations. Some of the new programs are already underway and in-place programs and facilities will be used and expanded as appropriate. The government has listed its relevant, ongoing research projects. That list has been reviewed by industry for applicability to PNGV. Industry and government are in the process of visiting various Federal laboratories and reviewing and coordinating program plans.

In addition, the Partnership is working to identify any gaps in the program, not covered by existing program plans, or which are not sufficient to address the aggressive PNGV targets. Teams are also working to focus joint resources more effectively on the key pacing problems and to eliminate any unnecessary overlaps that may be discovered.

8.0 MANAGEMENT PLAN

8.1 Operating Roles

The PNGV consists of two main organizational units, the Operational Steering Group and the Technical Task Force (see Section 2.0). Each of these two bodies contains both government and industry participants, which ensures there is mutual agreement on all key PNGV activities and decisions. The primary management responsibilities are as follows:

The **Operational Steering Group** is responsible for
- Strategic planning,
- Program review and prioritization,
- Availability of program resources and funding,
- Coordination of legal and public affairs functions, and
- Direction to the Technical Task Force.

The **Technical Task Force** is responsible for
- Planning, development, and implementation;
- Project management;
- Coordination of technical expertise among government and industry;
- Communication of progress to the Operational Steering Group; and
- Outreach to outside parties.

The Operational Steering Group is supported by both government and industry **Legal Groups**, **Public Affairs Groups**, and **Congressional/Legislative Groups**, which provide technical expertise in their respective areas. Similarly, industry and government each have the support of their own Secretariat.

The **Government PNGV Secretariat** serves as a central point of contact. It is responsible for the storage and maintenance of non-proprietary data and information, the separate development and housing of the PNGV Library and Reading Room, dissemination of government information in response to public requests, and the establishment and maintenance of a physical facility for government support staff. **USCAR** similarly serves as the industry's administrative arm. Contact information is provided below.

PNGV Secretariat
U.S. Department of Commerce
Herbert Clark Hoover Building, Room 4845
14th Street and Constitution Avenue, N.W.
Washington, D.C. 20230
Phone: 202-482-6260
Fax: 202-482-6275

USCAR
330 Town Center Drive, Suite 100
Dearborn, MI 48126
Phone: 313-248-4300
Fax: 313-248-4303

8.2 Federal Agencies

Under the leadership of the Department of Commerce, eight Federal operating agencies are actively contributing to the development of new technologies for PNGV. Their areas of expertise in relation to the program are discussed next.

The **Department of Commerce's** National Institute of Standards and Technology (NIST) is a world-class center for physical science and engineering research. It has several major programs specifically designed to spur industrial innovation, accelerate the use of new technologies, and encourage industry to improve quality. NIST's research areas that could be applied to automotive technology include advanced materials, new manufacturing processes, high-performance computing and communications, advanced electronics and controls, environmental technologies, and measurement standards and techniques. The Advanced Technology Program has provided many awards which directly benefit the partnership.

The **Department of Defense** is engaged in the development of military vehicles with major improvements in performance and efficiency. DOD is specifically concerned with combat support of energy intensive vehicles and the need to reduce the cost and time required to complete design-to-production cycles. As a result, DOD has a number of automotive technology programs relevant to PNGV goals. The activities of these programs are being coordinated with PNGV through the U.S. Army Tank Automotive Research, Development, and Engineering Center (TARDEC), the world's largest producer of military ground vehicles, and the Advanced Research Projects Agency.

The **Department of Energy** has several transportation-related missions and capabilities relevant to the PNGV goals. Central to these missions is improved efficiency in energy use, diversity in energy sources, and improved environmental quality. Other DOE areas of expertise that can contribute to PNGV goals include the manufacturing and computational capabilities associated with the nuclear defense programs. DOE's ten national laboratories possess expertise, facilities, and resources that can directly contribute to achieving the goals of the Partnership. For example, the laboratories conduct research programs in advanced engine technologies such as gas turbines, hybrid vehicles, alternative fuels, fuel cells, advanced energy storage, and lightweight materials. DOE supports the national laboratories in establishing joint industry/national laboratory Cooperative Research and Development Agreements with the USCAR consortia. In these CRADAs, DOE funds the laboratories' efforts, while the industry funds its share of the work. A "master" CRADA has been developed as the model for all such efforts within PNGV, which will eliminate the need to constantly re-negotiate the general terms for these agreements.

The **Department of Interior** has as one of its missions to provide materials-conservation solutions to national problems through cost-shared, cooperative work. The Materials Research Partnership Center of the U.S. Bureau of Mines has capabilities and programs relevant to the PNGV goals at its materials research laboratory. Examples of this expertise include research programs relevant to low-cost titanium, corrosion, and mechanical performance of lightweight materials, casting of lightweight materials, recycling and reuse of alloys and composites, and synthesis and joining of advanced materials.

The **Department of Transportation** has designated the National Highway Traffic Safety Administration (NHTSA) as the coordinator for all DOT activities related to PNGV. NHTSA is responsible for conducting safety research and promulgating standards for Federal motor vehicles. As a result, its involvement in PNGV will help assure that any vehicles offered for sale possess structural integrity, include occupant protection systems, and do not compromise safety levels. Other components of DOT that will contribute to research in safety, materials, powertrain, and other technologies include the Research and Special Projects Administration, the Federal Highway Administration, and the Federal Transit Administration.

The **Environmental Protection Agency** is responsible for research, policies, and regulations in the enforcement of Federal programs related to air, water, and land pollution. Its National Vehicle and Fuel Emissions Laboratory (NVFEL) is specifically equipped to focus on high-payoff, high-risk automotive technologies to reduce pollutants, especially carbon dioxide emissions. Its focus will be to determine whether specific designs that could achieve the PNGV target fuel efficiency could also provide a commensurate reduction in greenhouse gases and criteria pollutant emissions.

The **National Aeronautics and Space Administration** represents a leading source of advanced technologies based on its historical role as the nation's civilian space agency. Its expertise will be used in the application of aerospace technology as well as in the development of advanced automotive technologies and propulsion systems to conserve energy and improve the environment. NASA will apply its expertise in three ways: by drawing upon existing space technologies such as systems analysis and advanced, lightweight, high-strength materials; by developing dual-use technologies such as advanced batteries and fuel cells to support both the automotive industry and aerospace programs; and by developing technologies specifically for PNGV, such as advanced power management and distribution technology.

The **National Science Foundation** conducts research on the enabling technologies that may provide the basis for major breakthroughs. It supports programs that are automotive-related and supports generic research in areas such as materials, engineering, manufacturing, sensors, and computer organization and operation.

8.3 Major Domestic Automakers

The United States Council for Automotive Research was formed by Chrysler, Ford, and General Motors in 1992, following successful cooperative research and development activities that began in 1988. USCAR is directed by a three-member council comprised of the Vice Presidents of the three auto companies. The mission of USCAR is to facilitate, monitor, and promote pre-competitive cooperative research and development.

Through this cooperative effort, resources can be coordinated more effectively to conduct research and evaluate alternative technologies to improve the automobile. The USCAR consortia can contribute to one or more of the three PNGV goals. Examples of research goals for some of these existing consortia are illustrated in Table 8-1.

Table 8-1. Industry Consortia Related to PNGV Research Goals

Consortia	Consortia Goals Related To PNGV Goals
Auto/Oil Air Quality Improvement Research Program	Develop data on potential vehicle emissions improvements from reformulated gasoline, alternative fuels, and new automotive technology
CAD/CAM Partnership	Promote and apply feature-based technology to reduce the complexity and costs of product and process design and tool manufacture
Environmental Research Consortium	Conduct research on the environmental impacts of vehicle and manufacturing emissions
Low Emissions Technologies R&D Partnership	Coordinate R&D activities on vehicle emissions technologies
Natural Gas Vehicle Technology Partnership	Conduct research on means to reduce the cost of storage tanks used in natural gas-powered vehicles
Supercomputer Automotive Applications Partnership	Perform high-performance parallel computing and communications research applied to vehicle design and development
U.S. Advanced Battery Consortium	Pursue research and development of advanced energy systems capable of improving the range and performance of electric vehicles
U.S. Automotive Materials Partnership	Conduct vehicle-oriented research and development in lightweight and other advanced materials and materials processing
Vehicle Recycling Partnership	Conduct research on recycling, reuse, and disposal of motor vehicles and vehicle components

9.0 RESOURCES AND FUNDING

Both government and industry have brought unique strengths to the Partnership. The industry partners are best equipped to determine which product concepts make the most sense to pursue from a marketing perspective. Their expertise in mass production for domestic and international markets is essential to convert any advanced technical idea into a practical product. Federal agencies have access to advanced research facilities not typically available to private firms. For example, many technologies being developed for specific military or space applications may have direct relevance to PNGV. In other cases, Federal funds can be used directly to fund government/industry research partnerships if the technical risks are too great or the returns too distant to obtain adequate funding from the private sector alone.

In order to accomplish the defined goals of PNGV, government and industry will enter into various contracts, subcontracts, understandings, and cooperative research and development agreements as well as shared research arrangements. Some of the administrative mechanisms through which these arrangements can be made are listed in Table 9-1. (See Section 10.0 for an explanation of acronyms not previously defined.)

Table 9-1. Means for Cooperative Government Programs with Auto Industry

Agency	Administrative Mechanisms
DOC/NIST	ATP, SBIR, ERIP CRADA, R&D Contract
DOD/ARPA	TRP, SBIR, STTR, CRADA, BAA, R&D Contract
DOE	CRADA, PRDA, SBIR, STTR, R&D Contract
DOI	SBIR
DOT	SBIR, Cooperative Agreement, R&D Contract
EPA	SBIR, R&D Contract
NASA	SBIR, STTR, R&D Contract
NSF	Grant, SBIR, STTR, Cooperative Agreement, Research Awards

Participants in PNGV projects will share the cost of the enterprise using a variety of arrangements, including direct funding of research in industry or university facilities and cooperative research arrangements, which combine government and private research without transfer of funds. While the relative proportions of government and private funding will vary depending on the initiative and on the specific project involved, the general rule is that there will be significant cost sharing by industry and government. The proportion of Federal funding will be higher for high-risk projects in which the outcome is uncertain. The proportion of industry funding will be higher for technologies with a clear, near-term market.

10.0 PARTICIPATION IN PNGV

Participation in PNGV is open to all interested individuals and organizations that can make relevant and potentially important contributions toward the attainment of the established objectives. The Partnership will seek out technologies from any sources that might contribute to the goals of the initiative. Qualified individuals and organizations can submit proposals to receive government funds to pursue promising research and development work on PNGV-related technologies.

The major domestic automakers and the government have historically maintained a strong foundation of affiliation with other developers and suppliers of technology, including the supplier community, universities, small businesses, and individuals. Consistent with this heritage, PNGV is intent upon using the best ideas, concepts, technologies, and systems available in this broader community to meet its goals.

Bringing the users and suppliers of technology together into stable, long-term relationships can be an effective means to alleviate the high costs and risks associated with moving a new technology into the marketplace. To encourage this wide range of participation, members of the Partnership are already participating in public meetings, workshops, symposia, and conferences to disseminate information about the program and the technical needs of PNGV.

Currently, input or ideas may be submitted directly to the applicable government agency through their respective mechanisms. Government funding to support PNGV activities is currently available through existing programs within the eight participating Federal agencies. Each program, however, is empowered to award research funds to different types of organizations and through different types of funding mechanisms. Potential government funding sources include the following:

- **Advanced Technology Program (ATP)** under the National Institute of Science and Technology and the U.S. Department of Commerce;

- **Broad Agency Announcement (BAA)** under the U.S. Army Tank Automotive Command, U.S. Department of Defense;

- **Energy-Related Inventions Program (ERIP)** under the National Institute of Science and Technology, U.S. Department of Commerce, and the U.S. Department of Energy;

- **Program Research and Development Announcement (PRDA)** under the U.S. Department of Energy;

- **Small Business Innovation Research (SBIR)** programs under the Departments of Commerce, Defense, Energy, and Transportation, the Environmental Protection Agency, and the National Aeronautics and Space Administration;

- **Small Business Technology Transfer (STTR)** under the Department of Energy, Department of Defense, National Science Foundation, and the National Aeronautics and Space Administration; and

- **Technology Reinvestment Project (TRP)** under the Advanced Research Projects Agency (ARPA) of the U.S. Department of Defense.

Detailed descriptions of each of these programs, as well as their respective funding mechanisms, are listed in a government document entitled *Inventions Needed for PNGV*. This document also contains descriptions of the specific innovation needs for the major technical areas in the PNGV program and current solicitation information for each of the participating government agencies. Copies of *Inventions Needed for PNGV* may be obtained through the Government PNGV Secretariat at the address shown below. PNGV information may also be obtained through the World Wide Web Homepage located at **http://picard.aero.hq.nasa.gov/index.html**.

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APPENDIX A

Partnership for a New Generation of Vehicles: Operational Steering Group

U.S. Government

Mary L. Good, Department of Commerce, Chair

Joseph Bordogna, National Science Foundation
Bo Cutter, National Economic Council
Mortimer Downey, Department of Transportation
Christine Ervin, Department of Energy
Lionel Johns, White House Office of Science & Technology Policy
Anita Jones, Department of Defense
Henry Kelly, White House Office of Science & Technology Policy
Linda Lance, Office of the Vice President
Mary Nichols, Environmental Protection Agency
Arati Prabhaker, Department of Commerce
Alice Rivlin, Office of Management & Budget
Sam Venneri, National Aeronautics and Space Administration

Executive Secretary

James H. Kelley, Department of Commerce

Industry

Chairmen:
Francois Castaing, Chrysler
John McTague, Ford
Arvin Mueller, General Motors

Bob Mull, PNGV Director, Ford
Peter Rosenfeld, PNGV Director, Chrysler
Ron York, PNGV Director, General Motors

Executive Secretary

Mike Thomas, USCAR

Appendix B

Partnership for a New Generation of Vehicles: Technical Task Force, Executive Committee, Technical Directorate, and Interagency Support Group

U.S. Government

Robert Chapman, Department of Commerce, Chair
Pandit Patil, Department of Energy, Vice Chair

Walter Bryzik, Department of Defense
Han Dihn, U.S. Postal Service
Donald Dix, Department of Defense
Charles Gray, Environmental Protection Agency
John Gully, Department of Defense
Murray Hirschbein, National Aeronautics and Space Administration
Ralph Hitchcock, Department of Transportation
Rusty Kalyoncu, Department of Interior
Jay Lee, National Science Foundation
William Siegel, Department of Energy
Dennis Ward, Department of Defense
Tom Weber, National Science Foundation
Michael Wozny, Department of Commerce

Ex-Officio Members

Chairman of the Clean Car Coordinating Committee
Lisa Gaisford, Office of Management & Budget
Thomas Gross, Department of Energy
Jim Kelley, Department of Commerce
Henry Kelly, White House Office of Science & Technology Policy
Linda Lance, Office of the Vice President
Randy Steer, Office of Management & Budget

Industry

Bob Mull, PNGV Director, Ford
Peter Rosenfeld, PNGV Director, Chrysler
Ron York, PNGV Director, General Motors

Mike Thomas, Executive Director, USCAR

Appendix C

Partnership for a New Generation of Vehicles: Other Supporting Groups

Legal Group

U.S. Government	Industry
Mark Bohannon, Department of Commerce	Norm Thorpe, General Motors

Public Affairs Group

U.S. Government	Industry
Virginia Miller, Department of Commerce	Scott Fosgard, United States Council for Automotive Research

Congressional/Legislative Group

Government

Linda Lance, Office of the Vice President

APPENDIX D

Glossary of Acronyms

ACC - Automotive Composites Consortium
ARPA - Advanced Research Projects Agency
ATP - Advanced Technology Program
BAA - Broad Agency Announcement
BTU - British Thermal Unit
C-4 - Clean Car Coordinating Committee
CEQ -Council for Environmental Quality
CRADA - Cooperative Research and Development Agreement
DMFC - Direct methanol fuel cell
DOC - Department of Commerce
DOD - Department of Defense
DOE - Department of Energy
DOI - Department of Interior
DOT - Department of Transportation
EPA - Environmental Protection Agency
ERIP - Energy-Related Inventions Program
ESST - Engine Support System Technology
FMVSS - Federal Motor Vehicle Safety Standards
GM - General Motors
IASG - Interagency Support Group
LEP - Low Emissions Partnership
NASA - National Aeronautics and Space Administration
NEC - National Economic Council
NHTSA - National Highway Traffic Safety Administration
NSF - National Science Foundation
NVFEL - National Vehicle and Fuel Emissions Laboratory
NIST - National Institute of Standards and Technology
OEM - Original equipment manufacturer
OMB - Office of Management and Budget
OSG - Operational Steering Group
OSTP - Office of Science and Technology Policy (White House)
OVP - Office of the Vice President
PEMFC - Proton exchange membrane fuel cell
PRDA - Program Research and Development Announcement
PNGV - Partnership for a New Generation of Vehicles
R&D - Research and development
RD&T - Research, development, and technology

SBIR - Small Business Innovation Research
STTR - Small Business Technology Transfer
TARDEC - Tank Automotive Research, Development, and Engineering Center
TEAM - Technologies Enabling Agile Manufacturing
TRP - Technology Reinvestment Project
USAMP - United States Automotive Materials Partnership
USPS - United States Postal Service
USCAR - United States Council for Automotive Research
USTA - Under Secretary for Technology

Inventions Needed

for

PNGV℠

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

Acknowledgments

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Inventions Needed
for

PNGV

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

Table of Contents

THE PARTNERSHIP FOR A NEW GENERATION OF VEHICLES (PNGV) 1

TECHNOLOGY AREAS 5

TECHNOLOGY STRATEGY 7

INNOVATION NEEDS 9
- Lightweight Materials 9
- Advanced Manufacturing 10
- Energy Conversion 13
  - Four-Stroke, Direct-Injection Engines 13
  - Fuel Cells 15
  - Turbines 16
- Energy Storage Devices 18
- Efficient Electrical Systems 19

HOW TO PARTICIPATE 21
- PNGV-Related Government Funding 21
  - Government R&D Funding Programs 21
  - Policies 26
  - Solicitations 26
  - Funding Mechanisms 27
  - Cooperative Research 27
- Further Help 28

INTELLECTUAL PROPERTY CONSIDERATIONS IN THE PNGV PROGRAM 29
- Summary of Rights by Program 29
- Intellectual Property Rights of CRADAs 32
- March-in Rights Under Contracts, Grants, and Cooperative Agreements 32

ACTIVE OR TYPICAL SOLICITATION TOPICS BY PROGRAM 33

THE PARTNERSHIP FOR A NEW GENERATION OF VEHICLES (PNGV)

Today's automobile forms an important component of the U.S. economy and has become an integral part of our way of life. It is therefore essential that we find cost-effective solutions to the issues of fuel efficiency and exhaust emissions. The Partnership for a New Generation of Vehicles, also known as PNGV, was formed to find these solutions. PNGV is a cooperative, collaborative research and development program between the U.S. Government and the U.S. Council for Automotive Research (USCAR), which is made up of the auto partners -- Chrysler, Ford, and General Motors.

PNGV's long-term goal is to develop vehicles that will deliver up to three times greater fuel efficiency (80 miles per gallon or BTU equivalent) and cost no more to own and operate than today's comparable vehicles (i.e., the 1994 Chrysler Concorde, Ford Taurus, and Chevrolet Lumina). At the same time, this new generation of vehicles should maintain the performance, size, and utility standards of today's vehicles and meet all mandated safety and emission requirements. It should be emphasized that the automakers will select the technologies, design the vehicles, and implement the manufacturing process for the new generation vehicles.

The development of energy efficient, low emission vehicles is important for both economic and environmental reasons. From an economic viewpoint, the introduction of a new generation of vehicles will preserve U.S. jobs and improve U.S competitiveness in the automotive market. A more competitive auto industry will improve the balance of trade, keeping more dollars in the domestic economy. On an environmental level, a new generation of fuel efficient vehicles promises such benefits as reduced exhaust emissions, which will improve air quality, and reduced gasoline consumption. The latter benefit will lead to reduced dependence on imported oil, further compounding the domestic economic benefits of PNGV.

The Partnership has three specific but interrelated technological goals:

1) **Significantly improve national competitiveness in manufacturing.**
    - Improve productivity of the U.S. manufacturing base by significantly upgrading U.S. manufacturing technology, including adoption of agile and flexible manufacturing and reduction of costs and lead times, while reducing the environmental impact or improving quality.

2) **Implement commercially viable innovation from ongoing research on conventional vehicles.**
    - Pursue advances in vehicles that can lead to improvements in the fuel efficiency and emissions of standard vehicle designs, while pursuing safety advances to maintain safety performance. Research will focus on technologies that reduce the demand for energy from the engine and drivetrain. Throughout the research program, the industry commits to apply those commercially viable technologies resulting from this research that would be expected to significantly increase vehicle fuel efficiency and improve emissions.

3) **Develop a vehicle to achieve up to 3 times the fuel efficiency of today's comparable vehicle.**
   - Achieve fuel efficiency improvement of up to three times the average of Concorde/Taurus/Lumina, with equivalent cost of ownership of today's comparable sedans adjusted for economics.

Accompanying these goals is an aggressive timetable for developing a new generation of vehicles (see Figure 1). To achieve these goals, PNGV is drawing on the technology development programs of eight participating government agencies: the Department of Commerce (DOC), the Department of Defense (DOD), the Department of Energy (DOE), the Department of Interior (DOI), the Department of Transportation (DOT), the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF).

During 1994, government and industry jointly identified technology areas (listed in the following section) in which advancements are needed in order to meet the PNGV goals. Within these areas, government and industry also identified various "candidate" technologies that are to be developed concurrently. By 1997, the focus of technology development will be narrowed down to only those "candidate" technologies that have become sufficiently developed and demonstrate adequate progress that they are likely to meet PNGV vehicle requirements within the established timeframe.

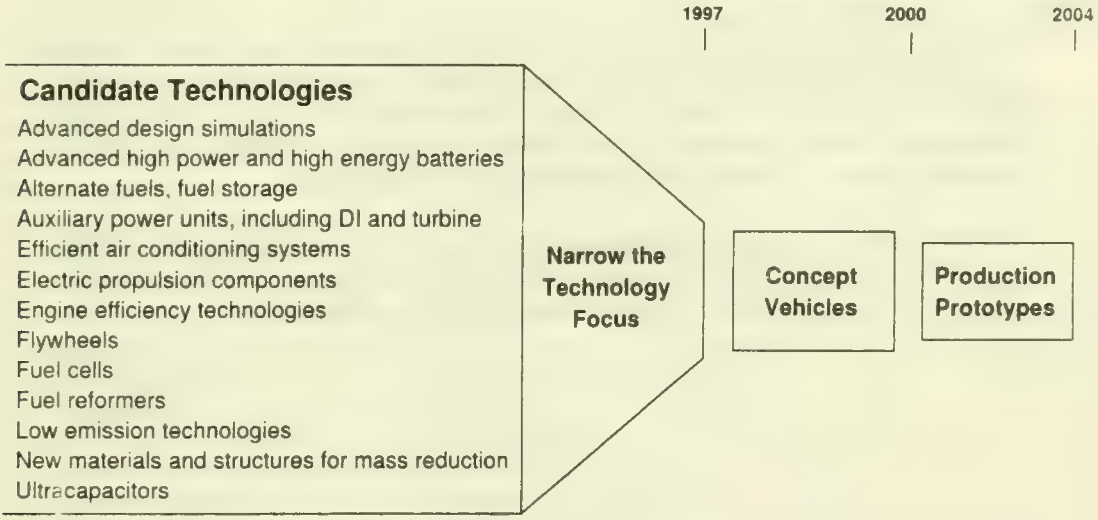
1997
2000
2004
Candidate Technologies
Advanced design simulations
Advanced high power and high energy batteries
Alternate fuels, fuel storage
Auxiliary power units, including DI and turbine
Efficient air conditioning systems
Electric propulsion components
Engine efficiency technologies
Flywheels
Fuel cells
Fuel reformers
Low emission technologies
New materials and structures for mass reduction
Ultracapacitors
Narrow the Technology Focus
Concept Vehicles
Production Prototypes

Figure 1. PNGV Timetable

As the technology focus is narrowed, the auto partners will use these technologies to develop *concept vehicles* in order to evaluate the engineering feasibility of incorporating these potential technologies into total vehicle systems. Development of these concept vehicles is expected by approximately 2000. As concept technologies are further developed through additional government and industry research and development, the auto partners will incorporate them into *production prototype vehicles.* These production prototypes which are expected in about 2005, will demonstrate the manufacturing feasibility of the technologies, as well as their ability to meet rigorous performance criteria.

Before the goals of PNGV can be realized, many advancements are needed in the identified technologies. These advancements may be accomplished through the continued development of current technologies or through the invention and application of new technologies.

What is a Concept Vehicle?

A concept vehicle is one that establishes functional benefits, demonstrates hardware availability in a systems context, and includes a rough workplan leading to production prototype verification of program parameters and commercial viability.

What is a Production Prototype?

This type of prototype is a soft tooled vehicle of a particular size, shape, material composition and powertrain, capable of being competitively mass produced within a three-to-five year time horizon, using commercially validated manufacturing technologies. When compared to high volume hard production tooling, soft prototype tooling is quicker to produce and change but has very limited life.

The prototype should demonstrate achievement of all functional attributes of the vehicle to evidence comparability with today's vehicle as defined above. The prototype will require confirmation of total systems integration by the industry.

TECHNOLOGY AREAS

Major improvements or innovations are needed in the following technology areas to enable the auto partners to build a new generation of vehicles. Within each of the areas, specific candidate technologies have been identified as warranting investigation. Although the identified technologies do not constitute a comprehensive list of all relevant research that is needed, they do provide a basic structure to assist researchers, scientists, engineers, and inventors in identifying relevant projects.

Technology Areas	Candidate Technologies
Advanced Lightweight Materials and Structures	- design optimization - high-strength steel - polymer matrix composites - metal matrix composites - ceramics - engineering plastics - aluminum, titanium, magnesium - joining technologies and adhesives - recycling - process/cycle time advancements in manufacturing
Advanced Manufacturing	- agile manufacturing (programmable machines and tools; near net-shape casting) - high speed data communication and data management - rapid prototyping and virtual manufacturing; high performance computing; complex visualization techniques - supercomputing - advanced forming technologies - advanced joining technologies
Energy Conversion	- four-stroke, direct-injection engines - turbines - fuel cells
Energy Storage Devices	- advanced high-power batteries - flywheels - ultracapacitors
Efficient Electrical Systems	- advanced electric motors - power electronics - efficient electric controllers (for regenerative braking, power management, signal distribution)

Technology Areas	Candidate Technologies
Waste Heat Recovery	- thermo-electric systems
Advanced Analysis and Design Methods	- simulations - fluid dynamics - structural mechanics - virtual prototyping - trade-off studies
Reduction of Mechanical Losses	- advanced lubricants - low-friction materials
Aerodynamics/Rolling Resistance Improvements	- simulation tools - new materials
Improved Efficiency of Internal Combustion Engines (Combustion Management)	- stratified charge/lean burn engines - direct injection - transient fuel control/fuel injection
Emissions Control	- advanced NO_x exhaust catalysts - on-board diagnostics (evaporative systems, catalyst diagnostics, engine misfire) - advanced particulate traps
Fuel Preparation, Delivery, and Storage	- pressure vessels - hydrogen storage alternatives - reformers/fuel processors
Interior Thermal Management	- low-emissivity windows - efficient heating, ventilation, and air conditioning (HVAC)

Although the preceding list is neither all-inclusive nor in priority order, the first five technology areas are particularly significant to PNGV. Innovations or breakthroughs in any of these areas, but particularly the first five, would have a tremendous impact on the success of the program. The following section provides information on the PNGV technology strategy and specific goals for the various candidate technologies. The first five technology areas are then discussed in terms of the inventions needed. This is followed by a section on how interested inventors can participate in this landmark research initiative.

TECHNOLOGY STRATEGY

Over the past 20 years, automotive fuel efficiency and emissions control have made significant progress through a combination of improvements to existing technologies and development of new technologies. Further improvements are currently being researched in weight reduction, design optimization, energy recovery, power source efficiency, alternative fuels, energy storage, energy conversion, etc. In order to achieve PNGV's demanding three times fuel efficiency goal, *major* advances must be made in many of these "feasible" technologies before they may become practical for use in production automobiles. These major advances must be made in several technologies simultaneously in order to achieve an 80 mpg vehicle.

Results from a parametric model, which has been used to show how these factors can be combined to achieve 80 mpg, are shown in Figure 2. This figure illustrates the approximate "design space" for one set of alternative approaches for achieving the goal. Three significant technical targets are to (1) improve the fuel efficiency of the primary fuel converter, (2) reduce the mass of the vehicle, and (3) implement efficient regenerative braking.

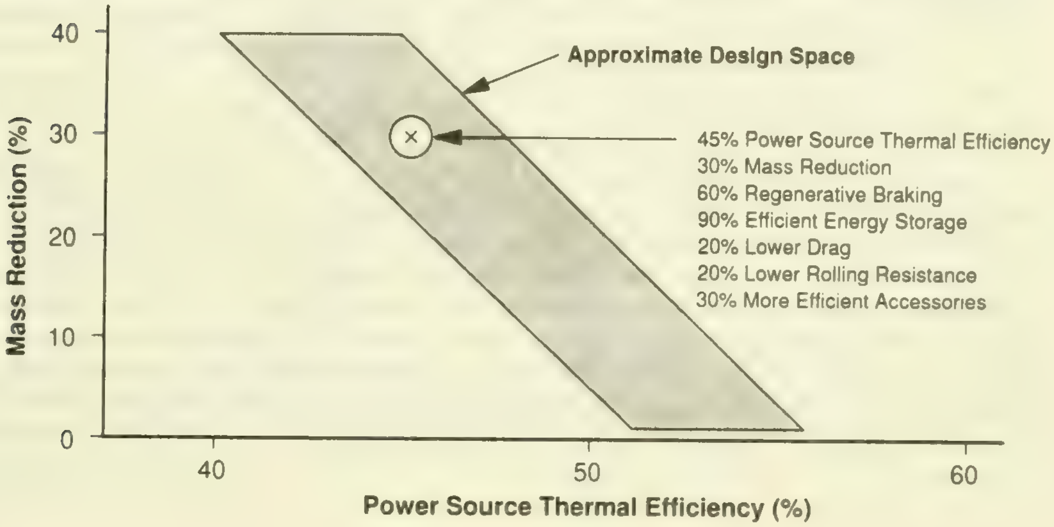

Figure 2. Achieving "3X" Fuel Economy Requires Major Improvements in All Powertrain and Vehicle Characteristics

The design space has both theoretical and practical limits. On the basis of realistically achievable thermal efficiencies of various heat engines, engine improvements alone may not achieve the fuel economy target. The thermal efficiency needed ranges from approximately 40 to 55 percent, which is about twice as efficient as today's engines. Even with advanced fuel cells, which have higher potential efficiencies than heat engines, other vehicle improvements are likely to be needed.

Models show that even with improved engines, an efficient regenerative braking system must be implemented to recover, store, and reuse energy currently lost when using brakes. This reduces the amount of energy which must be converted from fuel, normally the most inefficient step of the energy cycle.

Even with the improved power converters and regenerative braking, reductions in vehicle mass on the order of 20 percent to 40 percent from today's baseline vehicles are required. These levels of mass reduction are beyond simple refinement of today's steel frame, steel body construction, and may involve the introduction of entirely new classes of structural materials.

Several other advances must be made, though these contribute less to the overall system goal, including reduced aerodynamic drag, reduced tire rolling resistance, and more efficient accessories.

INNOVATION NEEDS

The goal of creating commercially viable vehicles capable of up to 80 miles to the gallon within a decade is very aggressive but projected to be achievable. Attainment of the cost and functional considerations, however, significantly compounds the task. Solutions to the challenges facing PNGV in this endeavor are neither assured nor known. They may necessitate the use of whole new technologies and inventions.

The Partnership has identified automobile weight, advanced manufacturing technology, principal power source efficiency, energy storage, and electrical system efficiency as the systems most in need of new inventions to obtain the necessary improvements for a new generation of vehicles. Each of these areas has been analyzed in order to highlight predominant technological barriers, potential solutions, and the inventions needed to make the technology feasible for PNGV application. A key obstacle to developing any of these technologies for affordable mass production is the cost of materials, and the cost, robustness, and speed of manufacturing processes.

Lightweight Materials

PNGV needs to find a way to cost-effectively process and fabricate the lightweight components necessary to substantially reduce vehicle mass and, consequently, significantly improve fuel efficiency. Mass reduction is a proven method for obtaining improved fuel economy in vehicles. For every 10 percent reduction in the mass of a vehicle, over 5 percent improvement in fuel economy can be expected. However, the challenge is to achieve mass reduction without compromising passenger comfort and safety, or sacrificing handling, performance, reliability, or cost. Reduction in mass could be accomplished through either innovative structural design (better utilization of materials), through the replacement of current components with lighter equivalents, or a combination of the two. Currently, vehicles are made primarily of mild steel. The materials that offer the best potential to replace it in significant proportions include high-strength steel, aluminum, polymer-based composites, metal matrix composites, and magnesium. While these advanced materials offer significant benefits for weight reduction, each also has substantial barriers to overcome in the areas of cost and manufacturing. It is worth noting that PNGV has prompted an aggressive weight reduction effort by the steel companies. The following table lists some examples of the inventions needed in materials and materials processing.

Challenges	Potential Solution	Invention Needed
Lack of low-cost, high-strength, high-stiffness materials	High-modulus fiber materials	Low cost carbon fiber materials
	High-strength, high-stiffness resins	New cost-effective resins
Lack of cost-effective, high-volume production processes for parts made from polymer-based composite materials	Fast molding process	Quick-acting catalyst or rapid-curing resin
	High productivity equivalent to hand lay-up process	Automated process to put oriented fibers or prepreg in place, i.e. fabrication of complex preforms
	Rapid curing of prepreg assembly	Rapid-curing resin or alternate fast-acting method to cure conventional resin (e.g., x-ray, ultrasound, etc.)
High cost of metal matrix composites	Develop lower cost materials	Economical high volume methods of making and fabricating metal matrix composites

Advanced Manufacturing

The goal of building an affordable vehicle means that new and innovative manufacturing technologies are essential. Some initial manufacturing needs which have been identified are shown in the following table.

Challenge	Potential Solution	Invention Needed
Lack of suitably robust systems and modeling methodologies to support vehicle manufacturers' evaluation of design and manufacturing tradeoffs in the early stages of development	Development of modeling and simulation methods which take the process (including prototype components) into account	Simulation and validation of manufacturing process, work cell, and tooling Alternate component/product development and validation cost models which take variability, reliability, and durability into account

Challenge	Potential Solution	Invention Needed
Lack of interoperability and flexibility of manufacturing equipment	Development of open architecture controllers	Controllers which accept modular hardware and software from multiple sources Controllers which accept plug and play type sensors, and strategies to affect the manufacturing process based on the sensory input
Fixturing is too individualized to the task and very human-intensive	Agile part fixturing	Flexible and reconfigurable fixtures for assembly and machining with adequate precision
Joining of aluminum components	Suitable mechanical fasteners	Practical rapid clinching or riveting systems
	Low-energy "spot welding"	Process similar to spot welding, perhaps based on laser system
	Practical adhesive bonding	Adhesive with consistent bonding with little surface preparation and without high-skill labor A sensor or inspection process that can detect defective bonds immediately during the assembly process
	Increased technology to assure reliability of spot welds	Control of distortion and part cleanliness Handle variety of joint configurations with increased joint efficiency Sensors and feedback to ensure the integrity and control of spot welds

Challenge	Potential Solution	Invention Needed
Machining of current and advanced materials	Dry machining	Tooling to allow dry machining High speed machining and high speed spindles
	Advanced cutting tools	Tools capable of longer life at higher speeds and feeds
Stamping processes are time consuming to redesign	Rapid tool & die fabrication	Technologies that will facilitate rapid development, validation and fabrication of tool and die designs. Improved prediction modeling for part dimension vs. die design
Stamping processes are most cost-effective for high volume parts	Develop low volume stamping process	Low-cost alternate sheet metal forming processes which emphasize small production volumes and rapid launch
CAD analysis tools are specialized and hardware/software specific	Flexible modeling system which meets needs of different disciplines	Standard feature definition language or format, which allows creation and exchange of information across multiple CAD systems User interfaces which allow feature concepts to be tested in a variety of development activities
Leak detection methods rely heavily on subjective human evaluation; are often unable to identify all small leaks	Leak detection methods or tools which can identify and locate leaks which are an order of magnitude smaller than can be detected by current equipment	Ultrasonic sensors, detectors, and new test methodologies

Challenge	Potential Solution	Invention Needed
Torque tools and methods often provide inconsistent clamp loads, require inspection, and cause worker injury	Improved torque tools which provide accurate clamping loads, without causing ergonomic injury	Automated closed loop feedback and adjusting mechanisms Ergonomic interface standards Advanced torque sensing methods and/or devices
Excessive cycle time and scrap in aluminum die casting	Improve aluminum die casting efficiency	Improved net-shape aluminum die casting methods Process modeling to optimize cycle time, die life, etc.
Painting processes create "bottleneck" in overall production process	Improve transfer efficiency	New paint materials Improved paint processes
Uniform steel spot welds	Improve technology to reduce the cost and improve the reliability of spot weld process	Improved welding processes and equipment Improved welder controls Sensors and processes to ensure the integrity and control of the weld Ability to handle a variety of joint configurations with increased joint efficiency

Energy Conversion

Four-Stroke, Direct-Injection Engines

Four-stroke, direct-injection (4SDI) engines are of interest to PNGV because of the technology's natural extension from port-injection, gasoline engines, which are widely used in the automotive industry. However, the thermal efficiency of current gasoline engines is only about 30 to 32 percent peak (about 23 percent on an in-use cycle). Even when combined with major vehicle changes (reduced mass and aerodynamic drag), a substantial improvement in engine efficiency will be necessary to approach the goal of tripling automotive fuel efficiency. Direct-injection diesel (compression ignition) engines have a higher baseline thermal efficiency (about 40 percent peak), 20 to 35 percent better fuel efficiency, 10 to 20 percent lower CO_2 emissions, near-zero evaporative emissions, low cold-start emissions, and demonstrated market acceptance in Europe. PNGV has specified goals for the 4SDI engine to increase thermal efficiency and reduce NO_x and particulate matter emissions. To accomplish these goals, 4SDI engines will require advances in technologies such as accelerated mixing and combustion; fuel injection spray pattern timing; engine-out and aftertreatment emissions; and cost-effective, high-pressure fuel injection componentry. The following table identifies some of the specific technological problems and inventions that could make the diesel alternative feasible.

Challenge	Potential Solution	Invention Needed
Higher pressures (more than 15,000 psi) on fuel injectors in DI engines	Higher pressure, electronically controllable injection systems	Redesigned injector
High NO_x emissions	Exhaust gas after-treatment	NO_x catalysts for lean burn engine, such as zeolite Compact plasma generator for electrical after-treatment of gas
	Combustion control using exhaust gas recirculation	Device for cooling exhaust gas before recirculation Means of providing inert gas instead of EGR
High particulate emissions	Particulate trap	Low-cost, durable materials and means of igniting and burning particulate off substrate
	More complete combustion	Means of providing more oxygen in the combustion process, improved mixing process
Improved thermal efficiency of the diesel engine	Use of bottoming cycle	Simpler bottoming cycle design, without expensive operating fluid or components
	Reduced friction	Improved engine coatings and materials

Fuel Cells

Fuel cells, electrochemical devices that convert chemical energy directly into electrical energy, are potentially high-efficiency devices. Also, they offer the likely advantages of low emissions and noise levels.

In a typical fuel cell system, hydrogen and oxygen (from air) react to produce electricity. The process requires a hydrogen source, which can be a hydrogen tank or a hydrogen-containing fuel and a reformer to extract hydrogen from the fuel.

Fuel cells have been used for years in the space program because of their high efficiency and reliability in providing high power. More recently, fuel cells have become commercially available for use in applications such as on-site power generators, and are currently being demonstrated in an urban bus environment. Their application in automobiles, however, is currently limited by size, weight, cost, and fuel availability. In order for fuel cells to meet performance, packaging, and cost requirements for use in mass production automobiles, further developments are necessary in the areas of response rate and start-up time; fuel storage, conditioning, and delivery; flexible fuel reformers; integration of the fuel cell, energy storage system, and electric drive and controls; power and energy density; specific power and energy; and lighter, smaller ancillary components (pumps, compressors, heat exchangers) that can improve dynamic response and handle load surges. Other complementary technologies such as high-power energy storage devices (batteries, flywheels, ultracapacitors) and lightweight materials are also needed to enable fuel cell vehicles to meet the 80 mile-per-gallon goal. Listed below are some inventions that may improve the performance and reduce the costs of fuel cell technology.

Challenge	Potential Solution	Invention Needed
Need higher power density for polymer electrolyte fuel cells	Improve the conductivity of the polymer membrane	High-conductivity, low-cost, stable membrane optimized for fuel cell operation
	Reduce the weight of the components and subsystems	Thinner (lighter-weight) bipolar plates
	Improve electrode performance	Highly dispersed alloy catalyst, optimized carbon supports, and thin film electrodes with uniform current distribution

Challenge	Potential Solution	Invention Needed
Need to reduce the cost of current fuel cell designs	Replace expensive, machined graphite parts and expensive membranes	Substitute coated metal or carbon composite materials for the plates; lower cost membranes; better utilization of catalysts; low-cost bipolar plate designs; low-cost fabrication methods
Fuel crossover in direct-methanol fuel cell designs	Electrolyte impermeable to methanol	Low-temperature, ceramic electrolyte High-temperature, polymer electrolyte
Low power density in direct-methanol fuel cell designs	Improve methanol oxidation kinetics	Oxygen-ion conducting, 450°C ceramic electrolyte

Turbines

Turbines are of interest to PNGV because of their high power density, high reliability, low emissions, and ability to run on a variety of fuels. Turbines are used extensively as auxiliary mobile power-units; however, their efficiencies for low-power applications (such as those required for PNGV) are inadequate. To overcome this drawback, government-funded research is oriented toward high-temperature turbines that will achieve thermal efficiencies near 40 percent. This effort focuses on the use of ceramics that can withstand high temperatures (2500°F). To be successful in PNGV, high-temperature turbines will have to overcome several problems related to cost, structural ceramics, emission control, heat recovery, and insulation. The following are some inventions that could make the turbine attractive as the main power unit for PNGV.

Challenge	Potential Solution	Invention Needed
High temperatures (typically 1800°F) at regenerator core seals	Low-friction, low-wear interface between regenerator core and seals	New seal coating compositions and deposition processes
Leakage past compressor and turbine blade tips	Active tip clearance control that reduces gap between blades and casing	High-temperature, high-resolution blade tip sensor for active feedback control of blade track position Durable, high-temperature coatings
Joining metal and ceramic components that operate at temperatures from room temperature up to 600°F	Compliant layer/glue	High-temperature elastomer that remains compliant at temperatures up to 600°F
Attachment of metal and ceramic components that operate at elevated temperatures (e.g., ceramic rings/raceways attached to metallic shafts)	Compliant pads/layers that accommodate differential expansion of components	Non-elastomer based springs/pads capable of operating at elevated temperatures
Oxidation of graphite components (e.g., seals) at elevated temperatures	Addition of stabilizers	Development of high-temperature graphite protection systems that can operate at temperatures in excess of 1200°F
Ceramic recuperator	Low-cost, light-weight, efficient recuperator	Manufacturing process with improved yield for production of ceramics
High-temperature materials	Cost-effective manufacturing of highly reliable ceramic components	Efficient, high-volume fabrication processes High-toughness ceramic materials

Energy Storage Devices

In today's cars, energy dissipated during braking can account for a significant portion of vehicle energy losses; much of this braking energy can be recovered with a regenerative braking system in which kinetic energy is recovered and stored for later use. In addition, a considerable amount of energy is lost during either deceleration or idling, which could also be stored for later use. Energy storage devices such as high-power batteries, ultracapacitors, and flywheels also allow the primary power source to run at more nearly optimum conditions where their efficiencies are greatest. Consequently, high-power energy storage devices that are lightweight and compact are essential to implementing a hybrid propulsion system with high fuel economy. To meet PNGV's goals, the energy storage device should store and release energy at high power levels with a round-trip efficiency of 90 percent or more.

Currently, cost is a major barrier for all energy storage technologies. High-power electrochemical battery technology must improve power performance, enhance durability, and reduce costs to become commercially acceptable. Ultracapacitors have high specific power and high charge/discharge energy efficiency, but need improvements in materials (such as carbon/metal fiber composites, monolith foamed carbon, foamed carbon with binder, doped polymer layers on carbon paper, and mixed metal oxides (ceramic) on metal foil) to improve their low specific energy and to reduce costs.

Flywheel systems have demonstrated suitable specific energy and power in commercial transit buses, but require simplification of the subsystems to reduce overall costs for the energy stored. Further R&D offers the potential to reduce material costs, provide lightweight containment, and simplify overall system integration. Potential technological solutions include improved processing and production of high-performance fibers, wet filament winding, in-situ or rapid curing, and multi-layer containment shielding based on low-cost metal matrix and polymer composites.

Challenge	Potential Solution	Invention Needed
Current batteries have power densities that are too low and costs that are too high	Develop cost-effective, high-power, bipolar batteries, e.g., lithium/iron disulfide	Thin (0.5 mm thick), stable, high-strength, low-resistance, fiber-based separators for lithium/iron disulfide bipolar batteries Corrosion-resistant, high-conductivity, bipolar plate material for bipolar lead-acid batteries

Challenge	Potential Solution	Invention Needed
Ultracapacitors have low energy densities	Use advanced materials to increase charge storage capability	Carbon/metal fiber composites Foamed carbon structures Mixed metal oxides on metal foils
Flywheels have low efficiency	Low-loss bearings	Inexpensive actively controlled magnetic bearings
	Inexpensive, no-leakage vacuum bottle	
	High-efficiency, low-cost, high-speed motor generator	
Flywheels require strong, lightweight shielding	Multi-layer containment shielding	Low-cost metal matrix, titanium, and/or polymer composites Improved structural integrity (of flywheel)

Efficient Electrical Systems

Efficient electrical systems are important to PNGV because they not only improve vehicle performance through fast control responses, but also improve vehicle fuel economy through battery charging, electric steering assist, active suspension, variable-speed compressors for air conditioning, and electric propulsion, along with regenerative braking. The efficiency of the electrical systems in today's vehicles could be improved through reduced energy losses in the many electrical accessories, as well as through integration of the other emerging technologies that manage and control high-power components and provide rapid, bi-directional energy flow among these components.

Continuing advances in power electronics, motor design, motor controllers, and permanent magnets have made possible the development of alternating-current (ac) powertrains. However, many additional advances are needed in order to reduce the present high cost, increase the specific power, improve the efficiency, and reduce the weight of the system. Optimization of several components in the system can help improve performance and reduce the cost of the technology. Some of these invention needs are highlighted below.

Challenge	Potential Solution	Invention Needed
Electric drivetrain energy losses, cost, and weight are too high	More efficient power conductors	More cost-effective, efficient power conductors
	More efficient and compact electric drive motors and actuators	Improved low-cost magnetic materials
	High power density electronics for power conditioning and control	Low-cost, high-power semiconductor devices
Energy losses in vehicle accessory systems are too high	Reduce climate control load	Electrochromic windows
	More efficient fractional horsepower electric drive motors and actuators	Improved low-cost magnetic materials
	Reduce climate control energy requirements	Reliable, high-efficiency, electric air conditioning system

HOW TO PARTICIPATE

Participation in PNGV is open to all interested individuals and organizations that can make relevant and potentially important contributions toward the attainment of its established objectives. Qualified individuals and organizations can submit proposals to receive government funds to pursue promising research and development work on PNGV-related technologies.

The auto partners and the government have historically maintained a strong foundation of affiliation with other developers and suppliers of technology, including the supplier community, universities, small businesses, and individuals. Consistent with this heritage, PNGV is intent upon using the best ideas, concepts, technologies, and systems available within this wider community to meet its goals.

Bringing the users and suppliers of technology together into stable, long-term relationships can be an effective means to alleviate the high costs and risks associated with moving a new technology into the marketplace. To encourage this type of relationship, members of the Partnership are already participating in public meetings, workshops, symposia, and conferences to disseminate information about PNGV and its technical needs.

PNGV-Related Government Funding

Government funds are available through existing programs within the eight participating Federal agencies. Each program, however, is empowered to award research funds to different types of organizations and for different types of projects and research topics. In addition, the programs employ different types of funding mechanisms. Interested parties should familiarize themselves with the programs, basic policies, solicitation information, and funding mechanisms which are summarized in the following pages. Selection of the most appropriate program and funding mechanism for a particular project will depend upon the type of applicant, the area or topic of research, and the solicitation topics that are currently active within each program.

Government R&D Funding Programs

Within the eight participating government agencies, the following programs provide support for PNGV-related research:

- **Advanced Technology Program (ATP)** under the National Institute of Science and Technology (NIST), U.S. Department of Commerce (DOC)

- **Broad Agency Announcement (BAA)** under the U.S. Army Tank Automotive Command (TACOM), U.S. Department of Defense (DOD)

- **Energy-Related Inventions Program (ERIP)** under the National Institute of Science and Technology, U.S. Department of Commerce, U.S. Department of Energy (DOE)

- **Program Research and Development Announcement (PRDA)** under the U.S. Department of Energy
- **Small Business Innovation Research (SBIR)** programs under the Departments of Commerce, Defense, Energy, Transportation (DOT), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF)
- **Small Business Technology Transfer (STTR)** under the U.S. Department of Energy, U.S. Department of Defense, National Science Foundation, and National Aeronautics and Space Administration
- **Technology Reinvestment Project (TRP)** under the Advanced Research Projects Agency (ARPA) of the U.S. Department of Defense

The following table indicates the types of entities eligible to participate through the various programs and mechanisms. As used in this document, the term "independent inventor" means an individual who has not previously set up a for-profit business, which would instead come under the heading of a small business.

Participant Eligibility for PNGV-Related Programs and Funding Mechanisms

Program	Large Business	Small Business	Research Institution	Independent Inventor
ATP (NIST/DOC)	Y	Y	N**	Y
BAA (TACOM/DOD)	Y	Y	Y	N
ERIP (NIST/DOE)	Y	Y	Y	Y
PRDA (DOE)	Y	Y	Y	N
SBIR (DOC, DOD, DOE, DOT, EPA, NASA, NSF)	N	Y	N	N
STTR (DOE, DOD, NSF, NASA)	N	Y	Y*	N
TRP (DOD/ARPA)	Y	Y	Y	N
Mechanism				
CRADAs (all)	Y	Y	Y	Y
Direct Contracts, Grants,	Y	Y	Y	Y

* only as secondary team member
** except as part of an otherwise qualified joint venture

Each of the government programs and technology support mechanisms listed in the table are explained briefly below. The chapter "Active or Typical Solicitation Topics" provides a list of the current solicitation topics for each of these programs.

Advanced Technology Program (ATP) An idea classified as high risk on the technical issues, but low risk on commercial viability, may be a candidate for funding by the U.S. Department of Commerce's Advanced Technology Program. ATP is administered by the National Institute of Standards and Technology. The projects selected for ATP funding have a relatively high technical risk, a long time horizon, and the potential for a broad-based economic impact.

ATP sponsors two types of awards. The first type is for general competition and accepts proposals on any subject. A second type is. for proposals responding to a set of 'focus' topics defined by NIST in response to white papers submitted by industry.

Broad Agency Announcement (BAA) The BAA is a funding activity administered through the Department of Defense Tank Automotive Command which is designed to award funds for advanced automotive technology development for ground vehicles where private research and development could be modified or augmented to satisfy future military vehicle needs, while still retaining a commercial value. This announcement is seeking collaborative advanced development of subsystems and components. Special emphasis will be directed towards improvements in vehicle/system performance, durability, maintenance; and reduction in vehicle weight and operation and support costs.

Energy-Related Inventions Program (ERIP) Of particular interest to small businesses and individual inventors is the Energy-Related Inventions Program administered by the Department of Commerce and the Department of Energy. The goal of ERIP is to stimulate economic benefits from the introduction of new, non-nuclear energy technologies developed by individual inventors and small companies. ERIP provides free technical and confidential evaluations of the inventions, furnishes financial and technical assistance and market intelligence to help develop promising energy-related inventions, and establishes a public-private partnership to speed commercialization of new technologies.

Program Research and Development Announcement (PRDA) The Program Research and Development Announcement is intended by the Department of Energy to be an occasional avenue for funding pre-competitive research on specific energy topics. No restrictions are placed on the makeup of the technical team, and teaming between large and small businesses and research institutions is encouraged. No preproposal white papers are expected or requested. The program requires cost-sharing, but the government's share can be up to 80 percent. Award amounts are expected to range from $400K to $1 million.

Small Business Innovation Research (SBIR) The Small Business Innovation Research program is designed to stimulate and foster scientific and technological innovation in the private sector, strengthen the role of small businesses in meeting Federal research and development needs, and increase the commercial application of innovations derived from Federally funded research. The

SBIR has established a phased, uniform process for soliciting proposals and awarding funding agreements for R&D on a competitive basis.

SBIR defines a small business as a for-profit enterprise operating in the United States with majority domestic ownership and not having more than 500 employees. SBIR awards are firm-fixed-price contracts not to exceed $50K to $100K under Phase I, the amount depending upon the agency. Follow-on awards (Phase II) with upper limits of $500K to $750K (depending on the agency) are available if project performance warrants. Any additional capital needed to commercialize a product must thereafter come from the private capital markets or other Federal support. University involvement in SBIR projects, while common, tends to be in a minor consulting or subcontracting role.

The government agencies participating in the SBIR program are the Department of Commerce/National Institute of Standards and Technology, Department of Defense/Tank Automotive Command, Department of Energy, National Aeronautics and Space Administration, National Science Foundation, and the Environmental Protection Agency. The following table shows the Federal agency or agencies responsible for PNGV technology areas under the SBIR program. Recall that, in addition, SBIR solicitations have focus topics that must be addressed specifically by your proposal.

Responsibilities by Technology Area of Agencies Participating in the SBIR Program

PNGV Technology Areas	SBIR Responsibility
Advanced Lightweight Materials & Structures	NIST DOE DOD NSF NASA
Energy Conversion	DOE DOD/ARPA NASA
Energy Storage Devices	DOE DOD/ARPA
Efficient Electrical Systems	NIST DOD/ARPA
Advanced Manufacturing	NIST DOE DOD/ARPA
Waste Heat Recovery	DOD/ARPA
Advanced Analysis and Design Methods	NIST
Reduction of Mechanical Losses	NIST SNF

PNGV Technology Areas	SBIR Responsibility
Aerodynamics/Rolling Resistance Improvements	NASA
Improved Efficiency or Internal Combustion Engines (Combustion Management)	DOD/ARPA DOD/TACOM EPA
Emissions Control	EPA
Fuel Preparation, Delivery, and Storage	DOE
Hotel Loads	DOD/ARPA
Advanced Crashworthiness or Occupant Protection Technology	DOT

Small Business Technology Transfer (STTR) The Small Business Technology Transfer pilot program is closely modeled on the SBIR with an additional requirement of co-participation by a research institution such as a university, non-profit institute, or a contractor-operated Federally funded research and development center (FFRDC). Objectives of this program include increasing private sector commercialization of technology developed through government-supported R&D, stimulating technological innovation in the private sector, and improving the return on investment from Federally funded research for economic and social benefits to the Nation.

Under the STTR Program, researchers at universities or other research institutions are encouraged to play a significant intellectual role in the conduct of cooperative research with a small business. Not less than 40 percent of the work conducted under an STTR award must be performed by the small business concern, and not less than 30 percent of the work must be performed by the non-profit research institution. The STTR awards, like SBIRs, are fixed-price contracts of approximately $100K under Phase I, rising to about $500K in Phase II, given continued successful program performance.

Technology Reinvestment Project (TRP) The Technology Reinvestment Project focuses on technology that has applications in both the U.S. defense arena and the commercial sector. TRP is a multi-agency, dual-use technology investment effort that includes the Departments of Defense (represented by the Advanced Research Projects Agency and the three Military Departments), Commerce, Energy, and Transportation; the National Science Foundation; and the National Aeronautics and Space Administration. The projects stimulate the transition to a growing, integrated, national technological capability that provides the most advanced, affordable military systems and the most competitive commercial products. All TRP Programs have common requirements, including specified minimum participation levels with an emphasis on "partnerships," cost-sharing between participants and the Federal Government, and defense relevance.

Policies

Participation of Non-U.S. Organizations

Because PNGV is a partnership with U.S. domestic companies and makes use of some research results, facilities, and expertise that were originally supported by U.S. taxpayers for national security purposes, non-U.S. suppliers and research entities generally may participate in government-funded PNGV activities *only* as sub-contractors or minority partners with a U.S. entity. One exception to this rule allows a U.S. corporation owned by a foreign company to receive research funding through the Advanced Technology Program if certain criteria are met.

Intellectual Property Considerations

The U.S. government recognizes that inventors are naturally concerned about the ownership of intellectual property rights to inventions and data developed through cooperative R&D. The government has therefore taken steps to clarify and safeguard the inventor's rights insofar as possible. These rights are subject to various regulations, however, according to the nature of the funding program and mechanism employed. The intellectual property rights of organizations and individuals contracting with the Federal government are briefly summarized by program in the following chapter.

Solicitations

Since many of the government's technology funding programs accept proposals only on those topics covered by active solicitations, it is important to be aware of the current solicitation topics. Announcements of funding programs and solicitations are published in the *Commerce Business Daily*, in popular technical publications such as *NASA Tech Briefs*, and in some technical journals. Synopsis of PNGV-relevant solicitations will also be posted on the PNGV electronic Bulletin Board on the Internet root gopher server **cypher.esusda.gov** [under the selection 'Americans Communicating Electronically (ACE),' choose 'National Policy Issues,' then 'Partnership for a New Generation of Vehicles.']

Many of the "inventions needed" technologies identified in this document may not be supported by an active solicitation at any given time, but these topics may be addressed by future solicitations, especially in response to white papers submitted by innovative organizations and individuals.

The chapter "Active or Typical Solicitation Topics" provides a list of the current solicitation topics for each of the government programs. Objectives, timelines, and contact information are also provided.

Funding Mechanisms

Innovators can gain support for technology development through the above programs using a variety of mechanisms, including contracts, subcontracts, grants, and cooperative agreements.

Grants and/or Cooperative Agreements Cooperative agreements, like CRADAs, allow joint pursuit of a common objective by government and industry, but in this case some government funding can be provided. Different regulations also apply to cooperative agreements.

Contracts The federal agencies issue thousands of procurement contracts each year in support of their day-to-day operations and agency-specific technical programs. These contracting opportunities are advertised in the *Commerce Business Daily.* Cold submittals for these contracts by individuals or companies unknown to the government contracting officers are unlikely to be successful. Your company should introduce itself to the relevant contracting office long before the specific contract you want comes up for bid.

Cooperative Research

Cooperative Research and Development Agreements (CRADAs) These agreements are mechanisms through which industrial partners can join Federal laboratories in a cooperative, 50/50 cost-shared research effort to pursue a project with mutual benefit. The laboratories are able to contribute personnel, equipment, and resources to the effort, but are specifically excluded from providing funds directly to an industrial partner.

Further Help

To avoid confusion as a result of this variety of programs, the Government PNGV Secretariat will provide advice to applicants on government funding policy and support for PNGV. Direct your inquiries to:

Government PNGV Secretariat
U.S. Department of Commerce
Herbert Clark Hoover Building, Room 7064
14th Street and Constitution Avenue, N.W.
Washington, DC 20230
Phone: (202) 482-6260
Fax: (202) 482-6275

Each agency will continue to conduct its own program awards. Therefore, PLEASE DO NOT SEND PROPOSALS TO THE SECRETARIAT.

INTELLECTUAL PROPERTY CONSIDERATIONS IN THE PNGV PROGRAM

Given PNGV's unique nature, issues may arise as to ownership of Intellectual Property (IP) created during performance of work using government assistance. The following is a general summary of intellectual property rights for the different funding mechanisms used for PNGV-related research and development. More detailed information can be found in each of the program solicitations. Should there be any discrepancy between this summary and the text of the solicitation, the policies of each solicitation should be followed. Generally, title to inventions rights and technical data are governed by the Bayh-Dole Act (found in 35 U.S.C.), which normally vests the title with the industry participant in order to promote maximum commercialization and utilization of Federally supported research and development by U.S. industry and labor. However, some of the funding mechanisms employed by PNGV are not necessarily governed by the Bayh-Dole Act. In those instances, there is some flexibility in negotiating IP rights for those that do not fall under 35 U.S.C.

Summary of Rights by Program

Federal agencies participating in the venture include the Department of Commerce/National Institute of Standards and Technology, the Department of Energy, the Department of Defense (TACOM, ARPA, ARO, AFOSR, ONR, and BMDO), the Department of Transportation, the National Aeronautics and Space Administration, the National Science Foundation, and the Environmental Protection Agency. The rules governing intellectual property rights vary from program to program with the different types of support mechanisms employed.

Advanced Technology Program (ATP)

Under this program, the award funding instrument used is a cooperative agreement. Title to inventions arising from assistance provided by the Program remain with the for-profit company or companies incorporated in the United States. For joint ventures involving a university, Federal laboratory, or non-profit independent research organization, only for-profit companies may retain title to patents resulting from ATP-sponsored R&D, although the non-profit entity may receive compensation. The government reserves a non-exclusive, non-transferable, irrevocable paid-up license to practice the invention or have it practiced for or on behalf of the United States, but will not publicly disclose any proprietary information related to the license. A company may license to others the intellectual property rights arising from assistance provided under this program.

Rights in technical data, including software shall remain with the contractor, except that the government shall have the unlimited right to use such data for government purposes. Proprietary data will not be released outside of the government without the permission of the contractor.

Energy Related Inventions Program (ERIP)

ERIP support is provided in the form of grants. Titles to inventions arising from assistance provided by ERIP remain with the company or companies incorporated in the United States. The government reserves a non-exclusive, non-transferable, irrevocable paid-up license to practice the invention or have it practiced for or on behalf of the United States, but will not publicly disclose any proprietary information related to the license.

Rights in technical data, including software shall remain with the contractor except the government shall have the unlimited right to use such data for government purposes.

Program Research and Development Announcement (PRDA)

Program Research and Development assistance is provided through direct contracts. The contractual requirements are governed by the Federal Acquisitions Regulations. Therefore, with regard to intellectual property rights, title to inventions arising from assistance provided by the Program remain with the for-profit contractor. The government reserves a non-exclusive, non-transferable, irrevocable, paid-up license to practice the invention or have it practiced for or on behalf of the United States, but will not publicly disclose any proprietary information related to the license. A company may license to others the intellectual property rights arising from assistance provided under this program.

Rights in technical data, including software, shall remain with the contractor, except that the government shall have the unlimited right to use such data for government purposes. Proprietary data will not be released outside of the government without the permission of the contractor.

Small Business Innovation Research (SBIR)

SBIR funding is awarded through contracts, grants, or cooperative agreements, which are subject to the Federal Acquisitions Regulations (48 C.F.R.). Small businesses normally may retain the principal worldwide patent rights to any invention made with an agency's support. In return, the Federal government receives a royalty-free license for Federal government use and requires that anyone exclusively licensed to sell the invention in the United States must normally manufacture it domestically. To the extent authorized by 35 U.S.C. 205, the agencies will not make public any information disclosing an agency-supported invention for a four-year period.

Rights in technical data, including software, shall remain with the contractor, except that the government shall have the limited right to use such data for government purposes and shall not release such data outside of the government without the permission of the contractor for a period of four years from completion of the project from which the data was generated, unless the data has already been released to the general public. However, at the end of the four-year period, the government shall retain a royalty-free license for government use of any technical data delivered under the contract.

Small Business Technology Transfer Program (STTR)

STTR funding is awarded through negotiated contracts similar to those awarded by the SBIR programs, with the exception of those cases in which a research institution is a partner.

Small businesses usually retain the principal worldwide patent rights to any invention made with an agency's support. In return, the Federal government receives a royalty-free license for Federal government use and requires that anyone exclusively licensed to sell the invention in the United States must normally manufacture it domestically. To the extent authorized by 35 U.S.C. 205, the agencies will not make public any information disclosing an agency-supported invention for a four-year period. Due to the requirement that small businesses team up with a research institution, the small business must negotiate a written agreement between the small business and the research institution allocating intellectual property rights before submitting an STTR proposal.

Rights in technical data, including software, shall remain with the contractor, except that the government shall have the limited right to use such data for government purposes and shall not release such data outside of the government without the permission of the contractor for a period of four years from completion of the project from which the data was generated, unless the data has already been released to the general public. However, at the end of the four-year period, the government shall retain a royalty-free, government-use license to any technical data.

Technology Reinvestment Program (TRP)

Funding of TRP projects is arranged through cooperative agreements, grants, or "other transactions." Since TRP is not a procurement, they do not fall under the rules, regulations, and procedures of the Federal Acquisition Regulations (FAR). Therefore, TRP has flexibility in how to structure agreement benefits. However, the SBIR Program of the TRP does use contracts, which are dictated by FAR.

Rights to intellectual property and technical data are flexible and are negotiated on a case-by-case basis. Normally, title to inventions arising from assistance provided by the TRP remain with the company or companies incorporated in the United States. The government reserves a non-exclusive, non-transferable, irrevocable, paid-up license to practice the invention or have it practiced for or on behalf of the United States, but will not publicly disclose any proprietary information related to the license. A company may license to others the intellectual property rights arising from assistance provided under this program.

Normally, rights to technical data, including software, shall remain with the contractor, except that the government shall have the unlimited right to use such data for government purposes.

Intellectual Property Rights of CRADAs

Cooperative Research and Development Agreements (CRADAs)

CRADAs were authorized by the Stevenson-Wydler Technology Innovation Act of 1980, as amended, which gave the Federal government and its industry partner more freedom to tailor IP rights and relieve them from the rules and regulations of the Federal Acquisition Regulations. Due to the flexibility in negotiating IP rights, each CRADA is handled on a case by case basis.

For PNGV-related CRADAs with the DOE National Laboratories, the Department of Energy has a master CRADA, which sets forth the guidelines concerning intellectual property. To briefly summarize, the party that makes the invention gets first rights to the title. If they elect not to retain title, then the other party may retain the title to the invention. If neither party chooses to retain the title, then the Department of Energy would take title of the invention. With regard to licensing, each party grants to the other party a paid-up, non-exclusive, world-wide license to practice the invention and the Government receives a paid-up, non-exclusive, non-transferrable, irrevocable, world-wide license to practice the invention for or on behalf of the United States.

March-in Rights Under Contracts, Grants, and Cooperative Agreements

With regard to march-in rights for each of the funding mechanisms, in order to ensure maximum commercialization and public availability of government-sponsored inventions, the Government reserves the right to require the patent holder to license to others in certain circumstances, such as if the title owner did not commercialize the invention. However, in the past, these rights have rarely been invoked.

ACTIVE OR TYPICAL SOLICITATION TOPICS BY PROGRAM

The funding cycles for each government agency and program tend to operate independently. In many cases, the latest round of solicitations provided for a given agency or program had already closed as this document went to press. Historical information from the closed round is nevertheless included in order to show a representative set of research topics characteristic to that agency. Note that the focus topics have been excerpted from each agency's current or most recent solication publication as "PNGV-related" topics and may change for each new round of solicitations.

ATP - NIST/Department of Commerce

BAA - TACOM/Department of Defense

ERIP - NIST/Department of Energy

PRDA - Department of Energy

SBIR - NIST/Department of Commerce
SBIR - Advanced Research Projects Agency
SBIR - Department of Defense
SBIR - Department of Energy
SBIR - Department of Transportation
SBIR - Environmental Protection Agency
SBIR - National Aeronautics and Space Administration
SBIR - National Science Foundation

STTR - Department of Defense
STTR - Department of Energy
STTR - National Aeronautics and Space Administration
STTR - National Science Foundation

TRP - ARPA / Department of Defense

ATP - NIST / Department of Commerce

ATP accelerates technologies that, because they entail significant risk upstream of product development, are unlikely to be developed in time to compete in rapidly changing world markets without such a partnership of industry and government. By sharing the cost of such projects with both large and small companies and with teams, ATP catalyzes industry to pursue promising technologies.

ATP has announced the proposal deadline for the 1995 general competition, which accepts project submissions from any area of technology. An estimated $25 million to $30 million in first-year funding will be available for ATP awards. Details on how to create proposals are found in the November 1994 *ATP Proposal Preparation Kit.*

The Commerce Department's National Institute of Standards and Technology (NIST) has also announced six new focused areas of technology -- all based on input from U.S. industry -- for which companies and consortia will be able to propose projects to receive nearly $800 million of long-range, cost-shared support under the Advanced Technology Program.

The six new focused technology programs are founded on ideas from white papers submitted by industry and workshops held around the country. The projects will be cost-shared and carried out by industry. A five-year government investment of $785 million is expected to leverage an equal investment by industry. It is anticipated that the new ATP focused program areas -- all driven by industrial concerns -- will yield large benefits to the nation's economy by fostering technologies that will enable new or improved world-class products and industrial processes.

General Contact:

Advanced Technology Program
A430 Administration Building
NIST
Gaithersburg, MD 20899-0001
Phone: 1-800-ATP-FUND (800-287-3863)
FAX: (301) 926-9524
Email: atp@micf.nist.gov (via Internet)

Detailed summaries of each of the six focused program areas as well as application packages for the general competition are available from the ATP contact noted above. Technical contacts for each focus area are listed below.

PNGV-related Topics:

Four of the new focus program areas are of possible application to PNGV:

1. ***Motor Vehicle Manufacturing Technology*** -- a five-year, $185-million program to foster innovations in manufacturing technologies that can strengthen capabilities and lead to dramatic advances along the entire automotive production chain, including more versatile equipment, better control and integration of processes, and greater operational flexibility at all levels. Automotive suppliers are expected to be key partners and players in this program.

PROPOSAL DEADLINE IS APRIL 11, 1995

For technical information, contact:
Jack Boudreaux, Program Manager
Phone: (301) 975-3560
FAX: (301) 926-9524
Email: jackb.enh.nist.gov

2. ***Catalysis and Biocatalysis Technologies*** -- a five-year, $160-million program to develop the tools, abilities, and theoretical insight to identify, design, and implement new catalysts and processes of major economic importance to chemical producers and users. (Catalysts are substances that alter a chemical reaction without being integrated into the resulting product or products.)

PROPOSAL DEADLINE IS APRIL 26, 1995

For technical information, contact:
Linda Beth Schilling, Program Manager
Phone: (301) 975-2887
FAX: (301) 926-9524
Email: schillin@micf.nist.gov

3. *Materials Processing for Heavy Manufacturing* -- a five-year, $145-million program to develop and demonstrate innovative materials processing technologies that will help U.S. heavy manufacturing companies make longer lasting, more reliable, and more efficient products. Examples of advances that could result from research in this focused area include truck engines that need overhauls only after 1.6 million kilometers (1 million miles), drive trains that require only half as much maintenance and repair, and a 2-percent increase in power-generation efficiency.

PROPOSAL DEADLINE IS MAY 3, 1995

For technical information, contact:
John Gudas, Program Manager
Phone: (301) 975-3214
FAX: (301) 926-9524
Email: gudas@micf.nist.gov

6. *Advanced Vapor Compression Refrigeration Systems* -- a five-year, $50-million program to develop more efficient, quiet, and compact air-conditioning and refrigeration systems with the lowest achievable environmental impact. The projects selected will focus on improving the vapor compression cycle, the principle of operation for most current cooling equipment. The overall technical goals are to increase system efficiency, reduce noise levels, and reduce the size of refrigeration components -- each by 25 percent -- and to design and manufacture a system in which no refrigerant leaks. (Ed. note: Automotive-sized equipment is specifically excluded from this competition, although the technology may be relevant to future vehicles.)

PROPOSAL DEADLINE IS APRIL 19, 1995

For technical information, contact:
Jim Hill, Program Manager
Phone: (301) 975-5851
FAX: (301) 990-4192
Email: jhill@micf.nist.gov

7. ***Manufacturing Composite Structures*** -- a five-year, $160 million program to trigger creation of a high-performance, commercial composite parts manufacturing infrastructure for surface transportation, civil infrastructure, and offshore oil production. Topics for this second-round competition include integrated design simulation methodologies, extrinsic and intrinsic sensors for manufacture and performance monitoring, and commercial manufacturing processes to enable low cost, large-scale, complex, modular or continuous shape production. The program scope also includes the testing and evaluation of prototypes which directly relate to the previously listed classes of potential commercial products.

PROPOSAL DEADLINE IS MAY 24, 1995

For technical information, contact:
Carol L. Schutte
Phone: (301) 975-6846
FAX: (301) 926-9524
Email: schutte@micf.nist.gov

Notes to the Focus Programs:

The planned funding levels for the six focused program areas in fiscal year 1995 and beyond are contingent on future appropriations for ATP. Proposals for focused program projects are accepted only in response to specific competition announcements published in the *Commerce Business Daily*.

Timeline (General solicitation only):

General competitions accept proposals on any subject.

Solicitation Published	November 1994
Last Solicitation Closed	**March 1, 1995**
Awards announced	
Negotiations complete	
Next solicitation anticipated	November 1995

(Excerpted from Document NIST 94-43 Press Release, dated December 2, 1994)

BAA - TACOM / Department of Defense

This Broad Agency Announcement is seeking collaborative advanced development of subsystems and components which will benefit future wheeled or trucked army combat vehicles and commercial vehicles. Abstracts and proposals should be prepared exclusively for tailoring or adapting ongoing automotive technology research and development in private business and non-business organizations.

Contact: J. Sterba
U.S. Army/Tank Automotive Command
AMSTA-AQ-WAA
Warren, MI 48397-5000
Phone: (810) 574-6792

PNGV-related Topics:

Technical topics of possible direct application to PNGV are: improving vehicle/system performance, durability, maintenance; and reducing vehicle weight and operation and support costs.

Timeline:

Solicitation Published	
Proposal Abstracts Due	April 30, 1995
Evaluation Completed	May 30, 1995
Full Proposals Due	**June 30, 1995**

Projected funding is expected to be around $1 million.

(Excerpted from DOD Solicitation DAAEO7-95-Q-BAA1)

ERIP - Department of Energy

Contact: Mr. Geroge P. Lewett, ERIP Director
Office of Technology Evaluation and Assessment
National Institute of Standards and Technology
Gaithersburg, MD 20899-0001
Phone: (301) 975-5500

PNGV-related Topics:

Any new energy-related concept, device, product, material, or industrial process with commercial potential may qualify for a first-stage evaluation (ask for an Evaluation Request [Form 1019]). If the invention is then rated as "promising," a second-stage evaluation is held. Successful passage of this stage allows the inventor to write a statement of work and qualify for a development grant. Extensive courses covering patents, licensing, market analysis, and other business issues are made available to the participants to increase their odds of success in the commercial marketplace.

Timeline:

Solicitation Published	Always open
Solicitation Never Closes	**Always open**
Awards announced	As granted
Negotiations complete	As granted
Next solicitation anticipated	Always open

Approximate Approval Rates: Of 29,000 inventions submitted to NIST for evaluation since 1975, more than 580 were recommended to DOE. More than 400 submitters received funding at an average value of $83K.

(Excerpted from Document DOE/CH10093-151 DE92010589, August 1992)

PRDA - Department of Energy

Contact: Robert A. Kost
U.S. Department of Energy
EE-321
1000 Independence Avenue, S.W.
Washington, DC 20585
Phone: (202) 586-2334
Email: Robert.Kost@hq.doe.gov

PNGV-related Topics:

1. ***Proton Exchange Membrane Fuel Cell***
   Novel, low-cost materials, catalysts, and fabrication techniques for advanced electrodes, membranes, lightweight bipolar plates, and ancillary stack hardware with the potential for greatly reduced costs and significantly improved performance. Hydrogen or reformate may be proposed as fuel.

2. ***Direct Methanol Fuel Cell***
   Development of new catalysts and electrode structures for the direct electrochemical oxidation of methanol as well as new membranes that prevent methanol "crossover" to the cathode. Development of new design and manufacturing techniques for the fuel cell and stack as well as ancillary stack hardware.

3. ***Solid Oxide Fuel Cell***
   Development of electrolyte materials with sufficient solid state conductivity, structural integrity, and chemical stability for low-temperature (450-650 °C) operation. Development of electrodes, materials (metallic as well as ceramic) for fuel cell and stack components, and low-cost processing and fabrication techniques.

4. ***Balance-of-Plant Components***
   a. Development of batteries, ultracapacitors, or other devices, specific to fuel cell propulsion systems, to provide short-duration peak power needed during acceleration and to store energy recovered during regenerative braking. The first application of a viable power management device is anticipated to be a fuel cell-powered bus.

   b. Development of high-efficiency, long-life, lubrication-free, wide flow range compressor/expanders for pressurizing fuel cell systems and subsequent recovery of energy from the high-pressure exhaust streams.

   c. Development of compact, high-efficiency fuel processors for the generation of hydrogen on-board the vehicle and compact hydrogen storage systems. Any fuel available today that is used or being considered as a transportation fuel may be proposed.

Timeline:

Solicitation Published	January 3, 1995
Solicitation Closes	**March 6, 1995**
Awards announced	
Negotiations complete	
Next solicitation anticipated	

Approximate Approval Rate: At least 4 awards are anticipated in the range of $400,000 to $1 million.

(Excerpted from DOE Document DE-RA08-95CE50384, January 3, 1995)

SBIR - NIST / Department of Commerce

The Department of Commerce (DOC) invites small businesses to submit research proposals under this solicitation entitled "Small Business Innovation Research (SBIR)." Firms with strong research capabilities in any of the areas listed are encouraged to participate. Unsolicited proposals are not accepted under the SBIR program.

Objectives of this solicitation include stimulating technological innovation in the private sector, strengthening the role of small business in meeting Federal research and development (R&D) needs, increasing the commercial application of innovations derived from Federal research, and improving the return on investment from Federally funded research for the economic benefit of the Nation.

Contact: Dr. Joseph M. Bishop
DOC SBIR Program Manager
1315 East-West Highway
Room 15342
Silver Spring, MD 20910-3232
Phone: (301) 713-3565
FAX: (301) 713-4100

PNGV-related Topics:

The following subtopics, within the Manufacturing Engineering and Material Science and Engineering topics, specifically apply to PNGV.

8.11.10TCC - *Selective Non-linear Processing for Real-time Machine Vision*
8.11.17TCC - *Machine Capability Management System*
8.11.18TCC - *Advanced Part Data Format for Rapid Prototyping Systems*
8.11.19TCC - *Generic Process Models for Manufacturing Simulation*
8.11.20TCC - *High Speed Communications and Data Management for Advanced Manufacturing*
8.11.21TCC - *Integration Mechanisms to Enable Virtual Prototyping of Mechanical Components*
8.14.8TCC - *Polymer Composites Durability in Infrastructure and Transportation Application*
8.14.9TCC - *Optimization and Control of Composite Manufacturing*
8.14.10TCC - *Dynamic Modulus Properties of Thermoplastics at High Pressure*
8.14.11TCC - *Monitoring Crack Growth at Solder Interfaces*
8.14.14TCC - *Sensors for Magnetic Nondestructive Evaluation (NDE)*

Timeline:

Solicitation Published	October 1994
Last Solicitation Closed	**January 11, 1995**
Last awards announced	September 1, 1995
Negotiations complete	September 30, 1995
Next solicitation anticipated	October 1995

Phase I contracts are limited to $50K.

(Excerpted from Document DOC 95-1, dated October 1994)

SBIR - ARPA

The FY 95 Technology Reinvestment Program (TRP) general solicitation will include a Small Business Innovation Research (SBIR) set-aside. SBIR proposals are invited in the Focus Areas specified for the Technology Development Competition Area ONLY. An SBIR Phase I proposal can be submitted in two ways -- a small business can associate with partners under the major TRP and embed a Phase I effort in that proposal, or it can submit a stand-alone SBIR Phase I effort.

General Contact:
Technology Reinvestment Program
Ph: (800) DUAL-USE (800-382-5873)
FAX: (703) 696-3813
Email: pa95-04@arpa.mil

Specific technical contacts are listed below.

PNGV-related Topics:

Topics of possible application to PNGV include:

3.2.1 *Affordable Advanced Controls Technologies*
Contacts:

Larry Stotts
ARPA
Advanced Systems Tech. Office
(703) 696-2367
FAX (703) 696-2206
lstotts@arpa.mil

Spiro Lekoudis
United States Navy
Office of Naval Research
(703) 696-4403
FAX (703) 696-2558
lekouds@onrhq.onr.navy.mil

3.2.2 *Affordable Polymer Matrix Composites for Airframe Structures*
Contacts:

Jon Devault
ARPA
Defense Science Office
(703) 696-2296
FAX (703) 696-2201
jdevault@arpa.mil

Steve Thompson
Air Force Wright Laboratory
Materials Technology
(513) 255-5151
FAX (513) 476-4420
thompssd@mlgate.ml.wpafb.af.mil(:ddn:wpafb)

3.2.4 *Ceramic Material Applications: High Performance Ceramics and CFCCs*

Contacts:

William Coblenz
ARPA
Defense Science Office
(703) 696-2288
FAX (703) 696-2201
wcoblenz@arpa.mil

Stanley Levine
NASA
Lewis Research Center
(216) 433-3276
FAX (216) 433-5544
slevine@01.lerc.nasa.gov

3.2.7 *Electric and Hybrid Tactical and Commercial Vehicles*

Contacts:

John Gully
ARPA
Advanced Systems Tech. Office
(703) 696-2348
FAX (703) 696-8401
jgully@arpa.mil

Dave Spiewak
Department of Transportation
RSPA
(617) 494-2771
FAX (617) 494-2961

3.2.8 *Low Cost Specialty Metals Processing*

Contacts:

Robert Crowe
ARPA
Defense Science Office
(703) 696-2229
FAX (703) 696-2201
bcrowe@arpa.mil

Doug Kaempf
Department of Energy
Headquarters/EE
(202) 586-5264
FAX (202) 586-3180
douglas.kaempf@hq.doe.gov

Timeline:

Solicitation Published	Completion delayed - unknown
Solicitation Closes	**Completion delayed - unknown**
Awards announced	May 1995
Negotiations complete	September 1995
Next solicitation anticipated	

Approximate Approval Rate: Not specified. Phase I awards limited to $99K.

(Excerpted from FY95 TRP Competition Document)

SBIR - Department of Defense

Contact: Mr. Bob Wren
SBIR Coordinator
U.S. Department of Defense
OSD/SADBU - The Pentagon, Room 2A340
Washington, DC 20301-3061
Phone: (703) 697-1481

PNGV-related Topics:

Topics of possible application to PNGV include:

U.S. Army Laboratory

OSD95 **-005** *Fluid-Filled O-Ring for Maintaining a Seal Under Low Temperature Conditions*
-009 *Optical Vibration Monitors in Gas Turbine Engines for Prognostic and Diagnostic Applications*

U.S. Navy Laboratory

OSD95 **-012** *Trivalent Chromium Conversion Coatings for Aluminum Alloys*
-015 *High Temperature Package for Recently Developed Silicon Carbide*
-016 *Elastomeric Composite Bumpers*
-017 *PAWS Off-Line Programming System*
-018 *Integrated Surface Treatment System*

U.S. Air Force Laboratory

OSD95 **-022** *High-Speed Electronic Imaging and Storage*
-023 *Multidisciplinary Design Optimization (MDO)*
-024 *Multiple Degree of Freedom Measurement (MDFM) System*
-025 *Advanced Tooling Manufacture for Composite Structures (ATMCS)*
-026 *Intelligent Machining Workstation (IMW)*
-027 *Measurement Techniques for Surfaces under Dynamic Contact*

Timeline:

Solicitation Published	
Solicitation Closes	**April 14, 1995**
Awards announced	by September 15, 1995
Negotiations complete	
Next solicitation anticipated	

Approximate Approval Rate: 40 Phase I awards limited to $100K.

(Excerpted from DOD Program Solicitation No. 95.2)

SBIR - Department of Energy

The Department of Energy (DOE) invites small businesses to submit research proposals under this solicitation entitled "Small Business Innovation Research (SBIR)." Firms with strong research capabilities in science or engineering in any of the topic areas are encouraged to participate.

Objectives of this program include increasing private sector commercialization of technology developed through DOE-supported R&D, stimulating technological innovation in the private sector, strengthening the role of small business in meeting Federal research and R&D needs, and improving the return on investment from Federally funded research for economic and social benefits to the Nation.

Contact: Mrs. Kay Etzler, Program Spokesperson
c/o SBIR Program Manager
ER-16
U.S. Department of Energy
Washington, DC 20585
Phone: (301) 903-5867

PNGV-related Topics:

Technical topics of possible direct application to PNGV are as follows:

1. *Novel Materials for Sustainable Energy Development*
3. *Ceramic Fibers and Fiber Coatings for High-Temperature Applications*
4. *Chemical Sciences Research*
6. *High Temperature Superconductivity for Energy Applications*
23. *Cost-Effective Methods for Coating Polymers*
37. *Natural Gas Utilization (gas turbines and fuel cells)*
41. *Lightweight Composite Material for Automotive Structures*
42. *Hybrid Electric Vehicle Technology*
44. *Technical Improvements for Advancing Photovoltaic Applications*

Timeline:

Solicitation Published	
Solicitation Closes	**March 1, 1995**
Awards announced	about July 1995
Negotiations complete	about September 1995
Next solicitation anticipated	about December 1995

Approximate Approval Rate: 1 in every 11 grant applications was awarded last round.
Approximate Approval Rate: 200 Phase I contracts are limited to $75K each.

(Excerpted from Document DOE/ER-0629)

SBIR - Department of Transportation

Contact: Dr. George Kovatch
DOT SBIR Program Director, DTS-22
U.S. Department of Transportation
Research and Special Programs
John A. Volpe National Transportation Systems Center
55 Broadway, Kendall Square
Cambridge, MA 02142-1093
Phone: (617) 494-2051
FAX: (617) 494-2497

PNGV-related Topics:

Subjects (numbered as in the solicitation) of possible relevance to PNGV include the following:

94-FA3 *Fire-resistant Thermoplastics for Aircraft Cabin Interiors*
94-FA5 *Raman Fiber-optic cure monitoring system for polymer composites*

Timeline:

Solicitation Published	
Last Solicitation Closed	**May 3, 1994**
Awards announced	October 1994
Negotiations complete	October 1994
Next solicitation anticipated	about March 1995

Approximate Approval Rate: 25 Phase I contracts are limited to $100K.

(Excerpted from Document DOT-VNTSC-OST-94-1, SBIR-94-1)

SBIR - National Aeronautics and Space Administration

Contact:
Mr. Mike Botaglia
SBIR Program Office
Code XC
NASA
Washington, DC 20546-0001
Phone: (202) 358-0120
FAX: (202) 488-7838
SBIR Electronic Bulletin Board: (800) 547-1811
Internet FTP: CONEY.GSFC.NASA.GOV

PNGV-related Topics:

Topics of possible relevance to PNGV are as follows:

01.01 *Internal Fluid Mechanics for Aeropropulsion Systems*
01.03 *Aeropropulsion System Instrumentation, Sensors, and Controls*
01.04 *General Aviation Propulsion Systems*
04.02 *General Aviation Aircraft Structures and Materials*
04.06 *Coating, Bonding, and Joining Technologies*
04.07 *Non-Destructive Evaluation of Material Properties*
04.09 *Structures for Propulsion and Power*
04.10 *Processable, Reliable, Low-Cost, High-Temperature Polymer Matrix Composites*
04.11 *Epoxy-Based Cryogenic Insulation*
10.02 *Thermal to Electric Energy Conversion*
10.03 *Energy Storage and Electrochemical Power Systems*

Timeline:

Solicitation Published	April 4, 1994
Last Solicitation Closed	**June 15, 1994**
Awards announced	September 30, 1994
Negotiations complete	December 15, 1994
Next solicitation anticipated	April 1995

Approximate Approval Rate: 380 Phase I contracts are limited to $70K each.

(Excerpted from Document SBIR 94-1)

SBIR - National Science Foundation

Contact: SBIR Program Director
Office of Industrial Innovation and Partnerships
Room 590
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Phone: (703) 306-1391
Email: stis@nsf.gov
Internet FTP: stis.nsf.gov

PNGV-related Topics:

NSF supports basic research in a wide variety of areas. The following topics were specifically identified as being applicable to PNGV.

1. ***Membrane research for fuel cells***
2. ***Intelligent control, sensors, and systems integration***
3. ***Power systems and integration (electrical)***
4. ***Catalysis***
5. ***Manufacturing, process control, and materials***
6. ***Enterprise integration and design technologies***
7. ***Social and economic issues***
8. ***Environmental issues***
9. ***Alternative fuel production and storage***
10. *Other*

Timeline:

Solicitation Published	
Last Solicitation Closed	**June 13, 1994**
Awards announced	December 31, 1994
Negotiations complete	December 31, 1994
Next solicitation anticipated	about March 1995

Approximate Approval Rate: 280 Phase I contracts are limited to $65K each.

(Excerpted from Document NSF-94-4)

STTR - Department of Defense

Contact:
Mr. Bob Wren
STTR Coordinator
U.S. Department of Defense
OSD/SADBU - The Pentagon, Room 2A340
Washington, DC 20301-3061
Phone: (703) 697-1481

PNGV-related Topics:

Topics with possible relevance to PNGV are as follows:

NAVY 95T001	*General Structural Materials*, e.g. composites and metal-ceramic hybrids.
NAVY 95T004	*Specific Structural Materials Processing*
NAVY 95T007	*Environmentally Acceptable Processes*, e.g. applying zero-volatile-organic paints using supercritical fluid.

For general information contact:
Mr. Vincent D. Schaper
Office of Naval Research 412E
800 North Quincy Street
Arlington, VA 22217-5660
Phone: (703) 696-4286

AF 95T007 *Innovative Applications Advanced Photonics*
a. Industrial Applications - Laser cutting/boring/drilling/welding

For technical information contact:
Robert Hancock
Phone: (505) 846-4418

AF 95T010 *Manufacturing Integration/Infrastructure Technologies*
a. Helioimaging Durable Product Generator
e. Near-netshape Casting Producing Machine

For technical information contact:
Marvin Gale
WL/MTX
Phone: (513) 255-7371

AF 95T011 *Electro Devices for Propulsion & Power Research*

For technical information contact:
Betty Siferd
Phone: (513) 255-2131

Timeline:

Solicitation Published	
Solicitation Closes	**April 7, 1995**
Awards announced	October 1, 1995
Negotiations complete	
Next solicitation anticipated	December 1995

Approximate Approval Rate: 70 Phase I awards are limited to $100K in funding.

(Excerpted from Document DOD Program Solicitation Number 95)

STTR - Department of Energy

The Department of Energy invited small business concerns to submit grant applications under the second annual solicitation for the Small Business Technology Transfer pilot program. Firms with strong research capabilities in science or engineering, in collaboration with research institutions are encouraged to participate in any of the topic areas described. Participation of a research institution in all STTR projects is a requirement of the program. DOE will support high-quality research or research and development on advanced concepts concerning important energy-related, scientific or engineering problems or opportunities that could lead to significant public benefit if the research is successful.

Contact: Mrs. Kay Etzler, Program Spokesperson
c/o STTR Program Manager, ER-16
U.S. Department of Energy
Washington, D.C. 20585
Phone: (301) 903-5867

PNGV-related Topics:

Topics (numbered as listed in the solicitation) of possible relevance to PNGV:

1. ***Production and Conversion of Cellulosic Biomass to Alternative Fuels***
   b. Ethanol Production Process
3. ***Environmentally Benign Physical and Chemical Processes***
   a. Environmentally Benign Chemical Processes
   b. Near Net Shape Forming of Materials
   c. Environmentally Benign Synthesis and Processing of Ceramics

Timeline:

Solicitation Published	
Last Solicitation Closed	**January 9, 1995**
Awards announced	about May 1995
Negotiations complete	about July 1995
Next solicitation anticipated	about October 1995

Approximate Approval Rate: 1 in every 23 grant applications was awarded during the last round.

(Excerpted from Document DOE/ER-0622)

STTR - National Aeronautics and Space Administration

Contact: National Aeronautics and Space Administration
Paul Mexcur, Code XC
STTR Program Manager
Washington, DC 20546-0001
Phone: (202) 488-2931
FAX: (202) 488-7838
E-mail: sbir@coney.gsfc.nasa.gov
Electronic bulletin board dialup:
[Nationwide except DC] (800) 547-1811
[DC] (202) 488-2939

PNGV-related Topics:

Selected topics of potential application to PNGV include the following:

01. ***General Aviation***

This topic seeks to reduce the cost, increase the safety, and expand the utility of general aviation aircraft by improving propulsion, flight planning, and pilot decision-making technologies for this class of vehicle. Proposals for cooperative research that support the conversion of technology resident in research institutions into products are solicited in:

- Advanced internal combustion and gas turbine engines and subsystems (e.g., propeller, gearbox/drive train, exhaust systems, combustors, etc.) that are capable of operating efficiently on fuels other than leaded aviation gasoline while producing lower emissions (NO_x and VOC) and noise levels than those of current propulsion systems and propellers.

- Expert systems, related sensors, data storage, data analysis for decision support, graphical depictions, and crew-vehicle system interfaces related to engine operation to improve safety and efficiency and to reduce emissions and operating and maintenance costs.

02. ***Advanced Materials and Structures for Aerospace Systems***

Proposals are solicited in the area of Active Materials and Enhanced Structural Performance for the development of materials and structural concepts that will help to improve the performance and reduce the weight and cost of aerospace structures. In particular, concepts derived from technologies resident in a research institution and having commercial potential are being sought for application in the development of materials and processes enabling smart materials, including sensors and actuators, that apply to both high performance aerospace and ground-based systems. Material systems of interest include piezoelectric and electrostrictive materials; optical fibers; films and coatings for sensing external stimuli; specialty polymers for scientific instrument packages; and oxidative-resistant polymers for films, coatings, adhesives, and matrix resins. Novel techniques are being sought for embedding sensors, actuators, and electronics into composite systems for active shape control and vibration stabilization.

03. *Energy Conversion Technology*

Proposals are sought that will stimulate the development of power conversion technologies to (1) improve performance at the system level and (2) reduce environmental impacts with reference to the current state-of-the-art. Proposals must provide for the commercialization of a technology that is resident in a research institution and that also meets a NASA interest in.

- Thermal-to-electric energy conversion including both static (thermoelectric, thermophotovoltaic, alkali-metal thermoelectric conversion) and dynamic (Brayton, Stirling, and Rankine) systems.
- Energy storage and electrochemical power systems including rechargeable batteries, fuel-cell-electrolyzer energy storage, lightweight flywheels, and ultra-capacitors.
- Power management and distribution with increased autonomous operation and efficiency including hardware, software, and overall electrical system concepts.

04. *Access to Space*

Proposals are solicited for the following specific areas that will support access to space:

- Improvements in turbomachinery utilizing a variety of techniques, such as bearing fault diagnostics using acoustic emission technology, concepts that increase lifetime of hydrodynamic bearings, and new methods for axial control of the Earth-to-orbit class of turbopumps during start and shutdown transients.
- Reusable cryogenic propellant tanks fabricated from advanced materials (e.g., composite structures).
- Improved vehicle and ground systems techniques for status monitoring and failure remediation, including advanced sensors, networking, and autonomous control capability.

Timeline:

Solicitation Published	January 10, 1995
Solicitation Closes	**March 23, 1995**
Awards announced	about July 1, 1995
Negotiations complete	
Next solicitation anticipated	January 1996

Approximate Approval Rate: 24 Phase I contracts are anticipated; limited to $100K each.

(Excerpted from Document 1995 NASA STTR.)

STTR - National Science Foundation

The National Science Foundation invites small business concerns to submit proposals for cooperative research with a nonprofit research institution under this Program Solicitation for Small Business Technology Transfer (STTR). STTR not only allows but requires researchers at universities and other research institutions to play a significant role in each STTR project.

Contact: STTR Program Manager
National Science Foundation
Room 590
4201 Wilson Blvd.
Arlington, VA 22230
Phone: (703) 306-1390

PNGV-related Topics:

Proposals for only one topic are sought.

Analytical Chemical Instrumentation

Research leading to the development of innovative instrumentation for the detection, identification, and quantification of chemical species is the focus of this solicitation. Such instrumentation will likely utilize new technologies or demonstrate new concepts. Examples include:

- New and improved analytical and characterization instruments and sensors having applications in chemistry, materials science, biotechnology, or environmental sciences.
- Analytical instrumentation for chemical processes, both batch and continuous.
- New or improved hardware and software components of analytical chemical instrumentation systems.

The scope of this solicitation is restricted to research leading to the development of analytical chemical instrumentation that responds to atomic or molecular species. It does not include analytical instruments that measure mechanical phenomena.

Prospective applicants are encouraged to discuss the appropriateness of their proposal, prior to submission, with the cognizant Program Director in the Chemistry Division at (703) 306-1856.

Timeline:

Solicitation Published	
Solicitation Closes	**April 3, 1995**
Awards announced	July 31, 1995
Negotiations complete	
Next solicitation anticipated	about January 1996

Approximate Approval Rate: The 10 Phase I contracts to be awarded are limited to $100K.

(Excerpted from Document NSF 93-95-30.)

TRP - ARPA / Department of Defense

General Contact: Technology Reinvestment Project
Phone: (800) DUAL-USE (800-382-5873)
FAX: (703) 696-3813
Email: pa95-04@arpa.mil

Specific contacts are listed below.

PNGV-related Topics:

Proposals in any dual-use area can be accepted into a single, very competitive category, but focus areas have been identified for priority funding. Those areas relevant to PNGV are as follows:

3.2.1 *Affordable Advanced Controls Technologies*

Contacts:

Larry Stotts
ARPA
Advanced Systems Tech. Office
Phone: (703) 696-2367
FAX: (703) 696-2206
Email: lstotts@arpa.mil

Spiro Lekoudis
United States Navy
Office of Naval Research
Phone: (703) 696-4403
FAX: (703) 696-2558
Email: lekouds@onrhq.onr.navy.mil

3.2.2 *Affordable Polymer Matrix Composites for Airframe Structures*

Contacts:

Jon Devault
ARPA
Defense Science Office
Phone: (703) 696-2296
FAX: (703) 696-2201
Email: jdevault@arpa.mil

Steve Thompson
Air Force Wright Laboratory
Materials Technology
Phone: (513) 255-5151
FAX: (513) 476-4420
Email:thompssd@mlgate.ml.wpafb.af.mil(:ddn:wpafb)

3.2.4 *Ceramic Material Applications: High Performance Ceramics and CFCCs*

Contacts:

William Coblenz
ARPA
Defense Science Office
Phone: (703) 696-2288
FAX: (703) 696-2201
Email: wcoblenz@arpa.mil

Stanley Levine
NASA
Lewis Research Center
Phone: (216) 433-3276
FAX: (216) 433-5544
Email: slevine@01.lerc.nasa.gov

3.2.7 *Electric and Hybrid Tactical and Commercial Vehicles*

Contacts:

John Gully
ARPA
Advanced Systems Tech. Office
Phone: (703) 696-2348
FAX: (703) 696-8401
Email: jgully @arpa.mil

Dave Spiewak
Department of Transportation
RSPA
Phone: (617) 494-2771
FAX: (617) 494-2961

3.2.8 *Low Cost Specialty Metals Processing*

Contacts:

Robert Crowe
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Timeline:

The next round of solicitations will open when advertised in the *Commerce Business Daily* on about February 3, 1995.

Announcement Published	October 21, 1994
Due Date for Concept Papers	December 21, 1994
Solicitation Published	**Completion delayed - unknown**
Due Date for Full Proposals	**Completion delayed - unknown**
Publication of Selections	May 1995
Negotiations complete	September 1995
Next solicitation anticipated	October 1995

(Excerpted from Program Information Package for Technology Reinvestment Project FY 95 Competition)

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